MINIMUM STANDARD 3.12

GENERAL INTERMITTENT SAND FILTERS

3.12A	Washington D.C. Underground Vault Sand Filter
3.12B	Delaware Sand Filter
3.12C	Austin Surface Sand Filter

View BMP Images

LIST OF ILLUSTRATIONS

#	FIGURES	PAGE
3.12-1	Austin Partial Sedimentation Surface Sand Filter	3.12-1
3.12-2	Flow Splitting Manhole Structure	3.12-11
3.12-3	Degradation of Hydraulic Conductivity of Denver Sand Filter	3.12-13
3.12-4	Full Sedimentation Basin on Austin Sand Filter	3.12-14
3.12A-1	Washington D.C. Underground Vault Sand Filter	3.12A-2
3.12A-2	Washington D.C. Sand Filter Cross-Section	3.12A-5
3.12A-3	Dimensional Relationship for a D.C. Sand Filter	3.12A-10
3.12A-4	Installing Precast D.C. Sand Filter Shell in Alexandria	3.12A-13
3.12A-5	D.C. Sand Filter Cross-Section with HDPE Infiltration Chamber Collection System	3.12A-14
3.12B-1	Precast Delaware Sand Filter as Used in Virginia	3.12B-2
3.12B-2	Dimensional Relationships for Delaware Sand Filter	3.12B-5
3.12B-3	Installing Precast Delaware Sand Filter Shell in Alexandria	3.12B-13
3.12C-1	Austin Full Sedimentation Sand Filter at Barton Ridge Plaza	3.12C-2
3.12C-2	Sedimentation Basin of Jolleyville Partial Sedimentation System	3.12C-3
3.12C-3	Underground Vault Fabricated from Precast Bridge Arch Components	3.12C-5
3.12C-4	Riser Pipe Detail for Full Sedimentation Basin	3.12C-14
3.12C-5	Austin Sand Filter Cross-Section with Filter Fabric Layer	3.12C-15
3.12C-6	Partial Sedimentation Vault Filter with Pea Gravel Layer	3.12C-16
3.12C-7	Restrictive Orifice Access Manhole	3.12C-19

LIST OF ILLUSTRATIONS cont.

#	TABLES	PAGE
3.12-1	Pollutant Removal Efficiency for Intermittant Sand Filter Facilities	3.12-2
3.12-2	Pollutant Removal Efficiencies for a Delaware Sand Filter in Alexandria	3.12-3
3.12-3	Appropriate Intermittant Sand Filter Applications to Various Site Areas	3.12-6
3.12-4	Percent of Street Pollutants in Various Particle Size Ranges	3.12-9
3.12A-1	Specifications for Nonwoven Geotextile Fabric on Top of D.C. Sand Filter	3.12A-7
3.12A-2	Specifications for Nonwoven Geotextile Fabric beneath the Sand in a D.C. Sand Filter	3.12A-7
3.12B-1	Specifications for Nonwoven Geotextile Fabric on Top of Delaware Sand Filter	3.12B-7
3.12B-2	Specifications for Nonwoven Geotextile Fabric Beneath Sand in Delaware Sand Filter	3.12B-7
3.12C-1	Cost of Austin Sand Filtration Systems	3.12C-4
3.12C-2	Clay Liner Specifications	3.12C-11
3.12C-3	Geotextile Specifications for Basin Liner Sandwich	3.12C-12
3.12C-4	Perforated Riser Pipes	3.12C-13
3.12C-5	Specifications for Nonwoven Geotextile Fabric Beneath Sand in Austin Sand Filter	3.12C-14

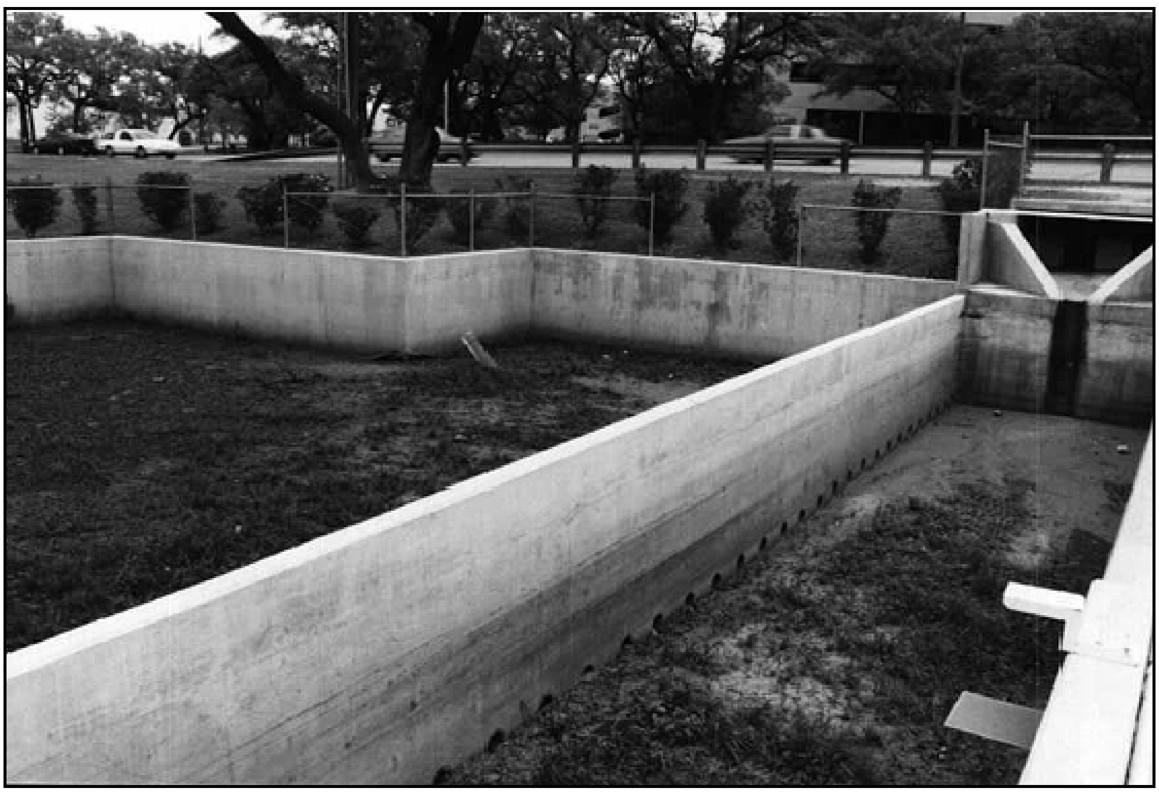
MINIMUM STANDARD 3.12

GENERAL INTERMITTENT SAND FILTER PRACTICES

Definition

Intermittent sand filter facilities capture, pretreat to remove sediments, store while awaiting treatment, and treat to remove pollutants (by percolation through sand media) the most polluted stormwater (the water quality volume) from a site. Intermittent sand filter BMPs may be constructed in underground vaults, in paved trenches within or at the perimeter of impervious surfaces, or in either earthen or concrete open basins. They have been successfully used in Austin Texas, the District of Columbia, The State of Delaware, and in Alexandria, Virginia over the last two decades. **Figure 3.12-1** is a photograph of a sand filter BMP in Austin.

FIGURE 3.12 - 1
Austin Partial Sedimentation Surface Sand Filter



(Photo Courtesy of City of Austin, Texas)

Purpose

Intermittent sand filter facilities are primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity facilities must be provided. Table 3.12-1 contains the target removal efficiencies of sand and other soil media filter BMPs. Table 3.12-2 contains the results of an extensive sand filter monitoring study in Alexandria conducted for the Chesapeake Bay Local Assistance Department (Bell, Stokes, Gavan, and Nguyen, 1995).

TABLE 3.12-1
Pollutant Removal Efficiency for Intermittent Sand Filter Facilities

BMP Description	Target Phosphorus Removal Efficiency
Intermittent Sand Filter treating 0.5 inches of runoff from the impervious area.	65%

Pollutant Removal Mechanisms at Work in Intermittent Sand Filter BMPs

Pollutant removal processes at work in intermittent sand filters are complex and involve physical, chemical, and biological transformations (Tchobanoglous and Burton, 1991; Anderson, Siegrist, and Otis, Undated). The most obvious mechanism is physical straining of suspended solids and particulate nutrients.

Suspended Solids

Mechanical straining, straining due to chance contact, and sedimentation are the principal mechanisms by which suspended solids are removed, although the growth of bacterial colonies within the sand grains may also cause autofiltration (Tchobanoglous and Burton, 1991).

Table 3.12-2
Pollutant Removal Efficiencies for a Delaware Sand Filter in Alexandria

Constituent	Mass Balance Removal Efficiency (%)
Cadmium	NA
Copper	NA
Zinc	>90.7
Iron	NA
Ammonia Nitrogen	>39.0
Nitrite Nitrogen	>45.8
Nitrate Nitrogen	-62.7
NO_x	-53.3
Total Kjeldahl Nitrogen	70.6
Total Phosphorous	63.1/72.3[1]
Ortho-Phosphorous	>68.3/74.4[1]
Total Suspended Solids	>78.8/>83.9[2]
Hardness	38.5
Biochemical Oxygen Demand (5 Day)	>77.5
Total Petroleum Hydrocarbons	>84[3]
Total Organic Carbon	65.9

[1] Excluding Anaerobic Incident Data [2] Excluding Storms with Heavy Iron Export
[3] Average Removal from Alaska Marine Lines Filter 3 in Seattle, Washington (Horner,1995)

Phosphorous

Phosphorous removal is performed by physiochemical processes such as mechanical and chance contact straining, precipitation, and adsorption (Piluk and Hao, 1989; Laak, 1986).

There are three general types of adsorption (the condensation and concentration of ions or molecules of one material [the adsorbate] on the surface of another [the adsorbent]): physical, chemical, and exchange. Physical adsorption results from the weak forces of attraction between molecules and is generally quite reversible. Chemical adsorption results from much stronger forces comparable to those leading to the formation of chemical compounds, with the adsorbed material forming a one molecule thick layer over the surface of the absorbent until the capacity of the absorbent is exhausted. Chemical adsorption is seldom reversible. Exchange adsorption, on the other hand, results from electrical attraction between the adsorbate and the surface, such as occurs with ion exchange. Ions of the adsorbate concentrate on the surface of the adsorbent as a result of electrical attraction to opposite charges on the surface. It is sometimes difficult to assign a given adsorption to a specific type (Sawyer, Mcarty, and Parkin, 1994).

Although exchange adsorption may also be involved, most adsorption in intermittent sand filters appears to be chemical adsorption (Piluk and Hao, 1989; Otis, Undated; Anderson, Siegrist, and Otis, Undated).

In addition to the **filter mass available**, the adsorption of phosphorous in sand filters is also affected by the pH of the material being filtered (with higher removal rates occurring with the reduction of pH), temperature, contact time, and the character of the filter media (Laak, 1986). Sands containing iron, aluminum, or calcium have a higher phosphorous removal potential because phosphorous will combine with these elements through chemical precipitation and become relatively insoluble (Laak, 1986, Tchobanoglous and Burton, 1991). If the filter becomes anaerobic, the bonding with iron may break down, releasing orthophosphates (Harper and Herr, 1993). However, aerobic filters enriched with iron may attain almost complete phosphorous removal until the filter capacity is exhausted, and properly sized filters may have a life of up to 20 years (Laak, 1986). Sand particles with sufficient iron content may become positively charged, leading to more favorable medium-particle interactions and increased removal rates (Stenkamp and Benjamin, 1994). Entrapment in the filter of a high percentage of the iron in the runoff being treated may provide a source to replenish used up phosphorous adsorption capacity.

<u>**Nitrogen and Biochemical Oxygen Demand**</u>

Mineralization of organic nitrogen into ammonium (NH^{+}_{4}) may occur under either aerobic or anaerobic conditions if the required naturally occurring chemoautotrophic bacteria (organisms which obtain energy by oxidizing simple chemical compounds) are present (*Nitrosomonas, Nitrosococcus, Nitrospira, Nitrosolobus, Nitrososovibrio*) ((Laak, 1986; The Cadmus Group, 1991).

Organic N 6 Bacterial enzymes 6 NH_4^+ + other products

Positively charged ammonium ions are then adsorbed to negatively charged sand filter particles through exchange adsorption (The Cadmus Group, 1991).

The transformation of ammonia (NH_3) and ammonium into nitrite and nitrate (NO_2^- and NO_3^-) and the removal of BOD_5 occur under aerobic conditions by microorganisms (such as *Nitrosomonas* and *Nitrobacter*) present in the sand bed (Tchobanoglous and Burton, 1991;, Laak, 1991; The Cadmus Group, 1991).

$NH_4^+ + 1.5O_2$ 6 *Nitrosomonas*, etc 6 $NO_2^- + 2H + H_2O$ + Energy

$NO_2^- + 0.5O_2$ 6 *Nitrobacter* 6 NO_3^- + Energy

Since nitrite and nitrate are soluble anions, they are not affected by the cation exchange complex of the filter, but rather tend to leach readily to the filter effluent (Gold, Lamb, Loomis, and McKiel, Undated). However, anaerobic microenvironments (sometimes called "microsites") routinely coexist in principally aerobic intermittent sand filters (Tchobanoglous and Burton,1991; Gold, Lamb, Loomis, and McKiel, Undated). Naturally occurring anaerobic bacteria (*Pseudomonas, Micrococcus*, *Achromobacter, Bacilluss*) in these pockets may convert much of the nitrite into nitrate and the nitrate to nitrogen gas, resulting in total nitrogen removal in intermittent sand filters ranging up to 45-50 percent (Tchobanoglous and Burton, 1991; Laak, 1986; Ronayne, Paeth, and Osborne, Undated).

NO_3^- + Organic Carbon 6 Denitrifying bacteria 6 $N_2 + H_2O + CO_2$ + Cells

Organic carbon must be present for denitrification to occur, but low organic carbon/nitrogen rations will suffice (1:2 or less) (Laak, 1986, p.62). Some studies indicate that optimal denitrification occurs at ratios of 1:1-3:1 (Gold, et al, p.298). The maximum rate of denitrification occurs at temperatures above 10 degrees C and at a pH above 5.5, with the optimum pH range falling between 7.0 and 8.0. (The Cadmus Group, 1991, p.11). However, home wastewater systems have demonstrated excellent denitrification performance when the wastewater temperature was as low as 4 degrees C (Piluk and Hoa, 1989).

Heavy Metals

More than 70 percent of heavy metals in stormwater runoff is in particulate form (Harper and Herr, 1993). Over 70 percent of particulate heavy metals are of greater than 104 microns in size (Shaver and Baldwin, 1990). Particle settling in presettling basins and mechanical straining appear to be the principal mechanism for removing heavy metals in stormwater intermittent sand filter systems. Some iron may be removed by reacting with phosphorous in the runoff being treated.

Hydrocarbons

Mechanical straining and physical adsorption appear to be the mechanisms removing hydrocarbons which reach the sand filter.

Conditions Where Practice Applies

Intermittent sand filters are suitable for use in ultra-urban settings with a high degree of imperviousness where the land cost or loss of economic return on real estate required to construct retention basins may be prohibitive. They are generally suited for high pollutant removal on medium to high density development (65 to 100% impervious cover). Specific conditions such as drainage area size and development conditions are discussed with each type of intermittent sand filter. Because they are subject to failure by clogging, intermittent sand filters are not recommended for use on watersheds where sediment loadings can be significant. Wherever possible, their use should be limited to treating runoff from impervious surfaces. Most of the practices discussed below are designed to treat runoff from watersheds with at least 65% impervious cover. Where other runoff must be treated, sediment protection must be increased to severely curtail the sediment load reaching the filter media.

Planning Considerations

Site Conditions

1. ***Size and Topography of the Site***

Some types of intermittent sand filter BMPs are especially suited to larger drainage sheds, while others have upper size limits on their effective use. **Table 3.12-3** outlines drainage shed size applications of various types of intermittent sand filter facilities. On larger sites with multiple drainage sheds, a variety of BMPs might prove to be most cost effective.

TABLE 3.12 - 3
Appropriate Intermittent Sand Filter Applications to Various Site Areas

Type of Intermittent Sand Filter	Appropriate Drainage Shed to filter
District of Columbia Underground Vault Sand Filters	Medium (0.25-1.25 impervious acres)
Delaware Sand Filters	Small-Medium ($\leq$ 1.25 impervious acres)
Austin Full Sedimentation Sand Filters (Surface or Vault)	Large ($\geq$ 1.25 impervious acres)
Austin Partial Sedimentation Sand Filters (Surface)	Medium-Large
Austin Partial Sedimentation Sand Filters (Underground)	Medium

2. *Stormwater Infrastructure Serving Site*

Both the size and the elevations of stormwater infrastructure serving the site as a whole are important considerations. A critically important design parameter is the potential difference in elevation of the receiving manhole in the stormwater infrastructure and the elevation of the closest manhole in the new storm sewer system draining the site to be served. This will determine the depth of water than can be pooled above the filter media with the system operating on gravity flow. Almost all intermittent sand filter BMPs are designed to flow by gravity. However, in commercial and industrial applications where dedicated maintenance crews with familiarity with mechanical equipment will be available, pumped flow should be considered a viable alternative.

3. *Depth to Seasonally High Groundwater Table*

The liner or concrete shell of intermittent sand filter BMPs is usually placed at least 2 to 4 feet above the seasonally high water table or bedrock in order to assure dry conditions for construction and to minimize infiltration of groundwater into the filter structure. However, in some cases, it may be economical and practical to place filter shells below the seasonally high water table. In such cases, floatation effects must be countered by providing extra weight or hold down components in the filter shell.

4. *Value of the Real Estate and Expected Income from Development*

The value of real estate in highly urbanized areas may drive the overall cost of traditional structural BMPs too high for serious consideration. In Alexandria, for example, the cost of real estate alone to construct retention ponds averages $60,000 per impervious acre treated, while the cost of real estate for extended detention basins averages $40,000 per impervious acre treated. The overall costs of underground vault sand filters, which may be placed under parking lots and private streets or even within building structures and therefore have no real estate cost, can become quite competitive under such circumstances. The income stream from increased development allowed by underground BMPs should also be considered in such analyses.

5. *Aesthetic and Land Use Considerations*

Most traditional stormwater BMPs may be severely lacking in visual attractiveness. This may be especially true with some extended detention basins and retention basins lacking a base flow to prevent eutrophication during hot, dry weather. Questions also often arise about the use of valuable open space on projects for BMPs instead of alternative uses such as recreation. Most sand filter BMPs are visually unobtrusive and may be used in situations where aesthetic considerations or open space use are important.

Sediment Control

Intermittent sand filter BMPs which have been subjected to heavy sediment loadings have historically failed very quickly (LaRock, 1988; Harper and Herr, 1993). In a study in Denver, Colorado, Urbonis, Doerfer, and Tucket found that the hydraulic conductivity of a sand filter serving an equipment parking lot dropped rapidly as sediment accumulated on the surface of the filter (Urbonis, Doerfer, and Tucker, 1996). A layer of sediment approximately 1/16 inch (1.6 millimeters) thick was found to limit hydraulic conductivity to 0.05 feet per hour (1.6 ft/day), considerably less than the design coefficient of permeability used by Northern Virginia jurisdictions in the design of sand filters (*ibid.;* Bell, Stokes, Gavan, and Nguyen, 1995). The filter media of intermittent sand filter BMPs must therefore be protected from excessive sediment loads. This requires isolation during construction of the development, site design to restrict the amount of runoff from pervious areas reaching the filter after construction, and proper sizing of sediment removing features of the BMP to match final site conditions.

1. *Construction Runoff*

> *Sand filter BMPS must* ***never*** *be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

When this precaution has not been taken in the past, the sand filter BMPs have become clogged with sediment from upland construction operations almost immediately, requiring complete reconstruction of the sand filter and sometimes the collector pipe system. This can prove very expensive. However, since most sand filter BMPs are constructed off-line with a flow splitting device employed to divert only the Water Quality Volume to the filter, the BMP may usually be completely constructed but isolated from runoff by blocking the inflow pipe until the site is fully stabilized.

2. *Urban Runoff*

While experience indicates that intermittent sand filters fail very quickly when directly exposed to runoff from watersheds with low imperviousness and poor vegetated cover (LaRock, 1988; Harper and Herr, 1993), filters which treat runoff from almost exclusively impervious areas, such as highway surfaces, may perform satisfactorily for several years with very little maintenance (Shaver and Baldwin, 1991).

An 18-month, comprehensive study of runoff from street surfaces in 12 cities throughout the U.S. determined that, while most particulate matter is in the fractions equating to sand and gravel, the approximately 6 percent of particles in the silt and clay soil size contain over half the phosphorous and some 25 percent of other pollutants (Sartor, Boyd, and Agardy, 1974). **Table 3.12-4** illustrates this finding.

In planning the layout for a site on which sand filter BMPs are to be employed, care should be taken to direct only runoff from impervious surfaces to the filter insofar as possible. The drainage sheds feeding sand filter BMPs with only partial sediment protection (as delineated in the individual BMP discussions which follow) should ***never*** contain less than 65% impervious cover. Even when full sediment protection is provided in the form of a carefully sized presettlement basin, the amount of runoff from pervious areas directed to the filter must be minimized. The Denver study also indicates that full sediment protection may be required in areas subject to heavy atmospheric deposition of suspended solids even when only runoff from impervious surfaces is being treated.

The presettling basin or sedimentation chamber of an intermittent sand filter BMP is expected to remove all but the very fine particles of sediment, while most of the other pollutant removal is expected to occur in the sand filter, where the very fine particles will be trapped.

TABLE 3.12-4
Percent of Street Pollutants in Various Particle Size Ranges

	Particle Size (Microns)					
Pollutant	**>2000**	**840-2000**	**246-840**	**104-246**	**43-104**	**<43**
Total Solids	24.4	7.6	24.6	27.8	9.7	5.9
Volatile Solids	11.0	17.4	12.0	16.1	17.9	25.6
COD	2.4	4.5	13.0	12.4	45.0	22.7
BOD_5	7.4	20.1	15.7	15.2	17.3	24.3
TKN	9.9	11.6	20.0	20.2	19.6	18.7
Phosphates	0	0.9	6.9	6.4	29.6	56.2
All Toxic Metals	16.3	17.5	14.9	23.5	-	27.8

(Source: Shaver and Baldwin, 1990; adapted from Sartor, Boyd, and Agardy, 1974)

Trash Exclusion

Underground vault BMPs are confined space under Occupational Safety and Health Regulations and are therefore more expensive to enter and maintain than open facilities. Future operations and maintenance costs can substantially reduced by assuring that trash is, insofar as possible, excluded from entering the vault. Grated storm inlets and trash racks in flow splitters are two ready solutions to this problem.

Projected Hydrocarbon Loadings

Sand filters will quickly clog when subjected to direct heavy hydrocarbon loadings. Where such loadings are expected, a design which removes unemulsified hydrocarbons in a separate chamber or structure in the treatment train ahead of the filter should be selected.

Maintenance

The maintenance requirements for intermittent sand filters must be considered during the planning and design of the facility. All chambers of underground sand filters must have personnel access manholes and built-in access ladders . Access roads or streets must be of sufficient width and bearing capacity to support dump trucks loaded with accumulated sediments or heavy vacuum (e.g.”VACTOR”) trucks for removing accumulated sediments and hydrocarbons from sediment chambers and traps on a regular basis. Approximately every 3-5 years, the filter can be expected to clog to the point that replacement of the top few inches of sand or, where employed, the layer of washed gravel and the top layer of filter cloth will be required. **A minimum maintenance headspace of 60 inches above the filter is required in underground vault filters BMPs.** A 36-38-inch diameter maintenance manhole with a small, concentric personnel access lid or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter. Large sedimentation basins and open filters must be equipped with access ramps to allow small earthmoving equipment such as “Bobcats” and light trash raking equipment to go into the basins. Finally, before finalizing the BMP design, follow the advice of Joseph J. Skupien, Principal Hydraulic Engineer of Somerset County, New Jersey, and “close your eyes, kick back, and think your BMP through a full year of operations, visualizing how it will perform under the conditions of all four seasons.”

General Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of intermittent sand filter practices intended to comply with the Virginia Stormwater Management program’s runoff quality requirements.

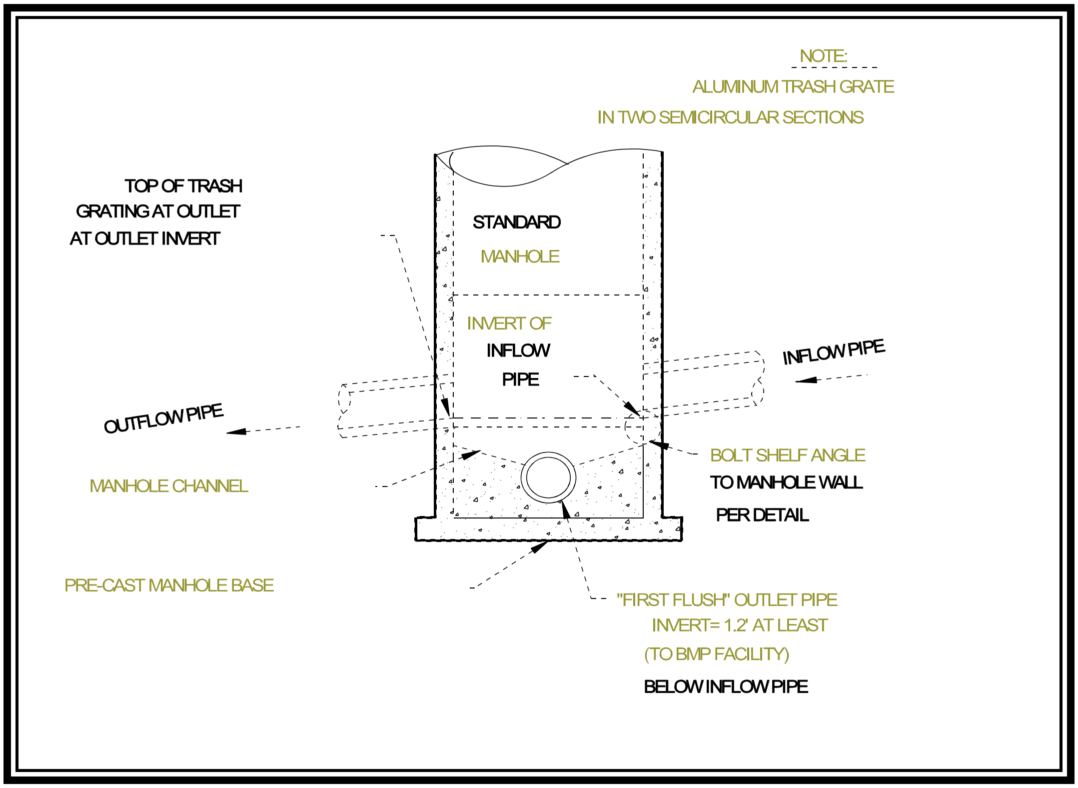
Several types of intermittent sand filter facilities are recognized for stormwater quality management purposes, including ***District of Columbia Underground Vault Filters***, ***Delaware Sand Filters, Austin Full Sedimentation Sand Filters,*** and ***Austin Partial Sedimentation Sand Filters***.

The general design criteria presented below apply to the design of intermittent sand filter facilities for ***water quality control***. This implies that the volume of runoff to be treated is determined by the **water quality volume** (the first 0.5 inches of runoff from the impervious surfaces on the site or drainage shed) and the desired pollutant removal efficiency.

Isolating the Water Quality Volume

The usual method for isolating the WQV is to construct an isolation/diversion weir in the stormwater channel or pipe, with the elevation of the weir set to allow overflow when the BMP is completely full. Additional runoff greater than the WQV spills over the weir to enter a peak flow rate reducer or exit directly to the storm sewer, minimizing mixing with the water in the BMP. Another approach is to provide a lower pipe to feed the filter until it fills, after which water rises in the slitter manhole and continues down a higher pipe. **Figure 3.12 - 2** illustrates this approach (source: Montgomery County, Maryland).

FIGURE 3.12 - 2
Flow Splitting Manhole Structure



Sizing Procedure

The majority of jurisdictions which are employing sand filter BMPs use hydraulic calculations based on Darcy's Law to establish the filter area that will allow flow-through of the treatment volume within the desired time frame, typically 40-48 hours (Austin, 1988, Shaver and Baldwin, 1991, Truong, 1989). Florida uses more complex falling-head computations and allows a drawdown time of up to 72 hours (Livingston, McCarron, Cox, and Sanzone, 1988). However, creating storage for the full WQV in shallow configuration systems may result in a larger filter than the hydraulic calculations would indicate (Alexandria, 1992).

Virginia uses the Austin Sand Filter Formula derived from Darcy's Law by the Austin Environmental and Conservation Services Department to size sand filters (Austin, 1988):

$A_f = I_a H d_f / k(h+d_f)t_f$ where,

A_f = surface area of sand bed (acres or sq. ft.)
I_a = impervious drainage area contributing runoff to the basin (acres or sq. ft.)
H = runoff depth to be treated (ft.)
d_f = sand bed depth (ft.)
k = coefficient of permeability for sand filter (ft/hr)

h = average depth (ft.) of water above surface of sand media between full and empty basin conditions (½ max. depth)
t_f = time required for runoff volume to pass through filter media (hrs.)

1. Coefficient of Permeability

When first installed, the coefficient of permeability of sand filters may be as high as 3.0 ft/hour, but these will typically decrease dramatically after the first few storms. Actual observations of filters in Austin, Texas, established that "ripe" filters stabilized in the range of 0.5-2.7 ft/day for filters with partial sedimentation control (Austin, 1988). This is probably caused by a combination of clogging of some filter pores from sediment loads and initial consolidation of the filter sand. **Figure 3.12 - 3** illustrates the similar rapid decrease in coefficient of permeability as sediment loads accumulated on a sand filter in Denver, Colorado (Urbonas, Doerfer, and Tucker, 1996). Falling head tests on a one year old Delaware Sand Filter in Alexandria, Virginia, resulted in an average coefficient of permeability of 8.5 ft/day (Bell, Stokes, Gavan, and Nguyen, 1995). The Alexandria filter was treating only runoff from pavement surfaces, and the mean input concentration of total suspended solids was only in the range of 75 milligrams/liter (75ppm)(*ibid)*. The Denver runoff, by contrast, had a mean concentration of 400 ppm (Urbonas, Doerfer, and Tucker, 1996), while the filters observed by Austin lacked full sedimentation protection. Use of conservative values for the coefficient of permeability is clearly indicated.

Based on long term observation of existing sand filter basins, Austin uses k values of 3.5 feet per day for systems with full sedimentation pretreatment and 2.0 feet per day for systems with only partial sedimentation pretreatment (full sedimentation pretreatment is defined as complete removal of particles with a diameter equal to or greater than 20 microns). Virginia jurisdictions utilizing intermittent sand filter BMPs have also adopted these values. Full sedimentation may usually be accomplished by capturing the WQV and releasing it to the filter over 24 hours. **Figure 3.12-4** illistrates a full sedimentation basin in Austin. Partial sedmientation basins, such as the one shown on **Figure 3.12-1**, should hold at least 20 percent of the WQV.

2. Drawdown time

Both Austin and the Virginia jurisdictions employ a BMP drawdown time (t_f) of 40 hours. This allows the filter to fully drain down and dry out to maintain an aerobic environment between storms (filters which remain continually wet may develop anaerobic conditions, under which previously captured iron phosphates may break down and wash out).

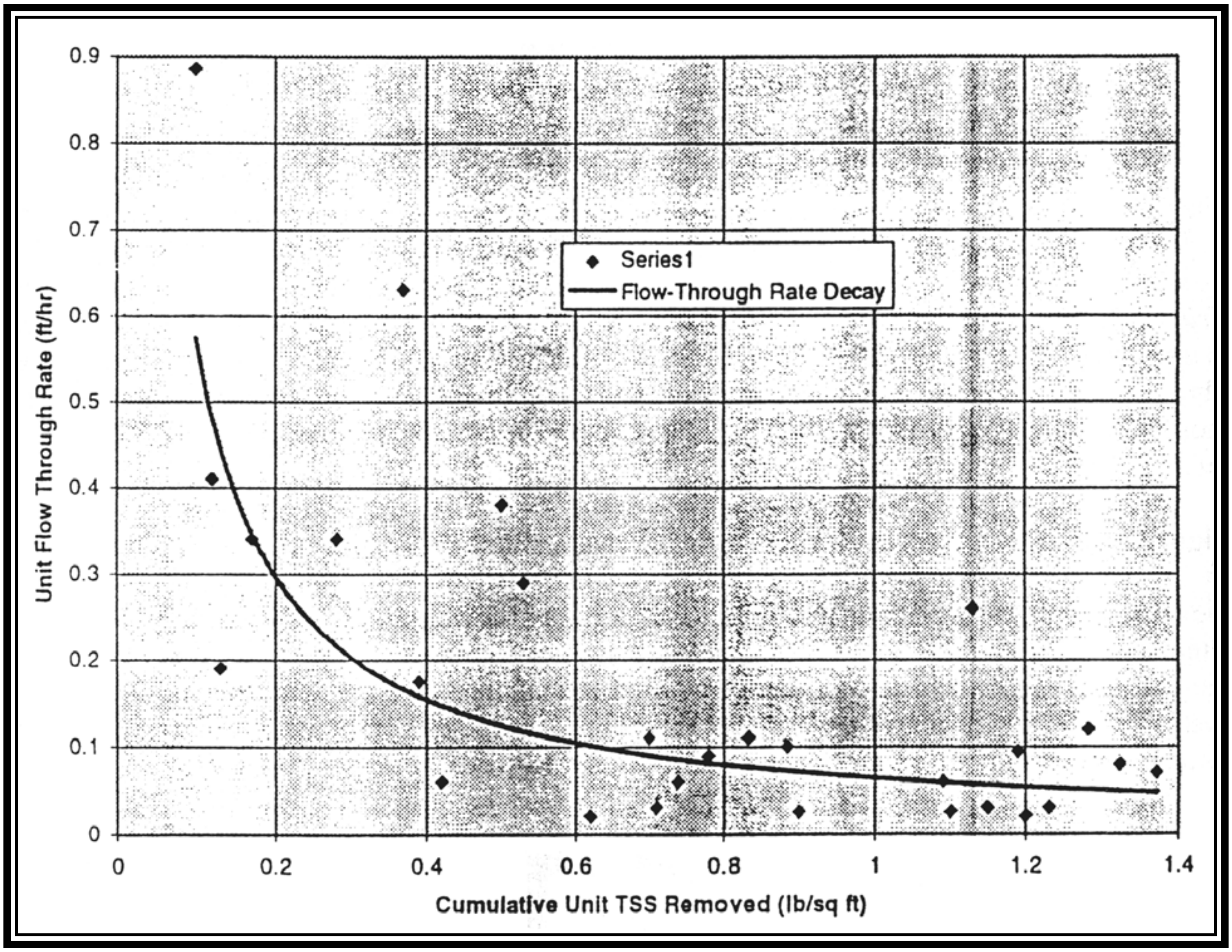
3. Simplified Filter Formula for Filters with Full Sedimentation Protection
(Sedimentation Basin containing full WQV with 24-hour drawdown to filter)

With k = 3.5 ft/day (0.146 ft/hour) and t_f = 40 hours, the sand filter formula reduces to:

$$A_{f(FS)} = 310 I_a d_f / (h + d_f)$$

where A_f is in ft^2 and I_a is in acres.

FIGURE 3.12-3
Degradation of Hydraulic Conductivity of Denver Sand Filter



(Source: Urbonas, Doeffler, and Tucker, 1996)

4. **Simplified Filter Formula for Filters with Partial Sedimentation Protection**
(Sediment Chamber containing 20% of WQV with free hydraulic flow to filter)

With k = 2.0 ft/day (.0833 ft/hour) and t_f = 40 hours, the formula reduces to:

$$A_{f(PS)} = 545 I_a d_f / (h + d_f)$$

where A_f is in ft^2 and I_a is in acres.

FIGURE 3.12-4

Full Sedimentation Basin on Austin Sand Filter

Exclusion of Continuous Flows and Chloronated Flows

Intermittent sand filter BMPs will **NOT** function properly if subjected to continuous or frequent flows. The basic principles upon which they operate assume that the sand filter will dry out and reaerate between storms. If the sand is kept continually wet by such flows as basement sump pumps, anaerobic conditions will develop, creating a situation under which previously captured iron phosphates degrade, leading to **export** of phosphates rather than the intended high phosphorous removal (Bell, Stokes, Gavan, and Nguyen, 1995). It is also essential to **exclude flows containing chlorine and other swimming pool and sauna chemicals** since these will kill the bacteria upon which the principle nitrogen removal mechanisms depend.

Continuous or frequent flows (such as basement sump pump discharges, cooling water,condensate water, ariesian wells, etc.) and flows containing swimming pool and sauna chemiclals *must be* ***EXCLUDED*** *from routing through intermittent sand filter BMPs since such flows will cause the BMP to* ***MALFUNCTION!***

Checklists

The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

MINIMUM STANDARD 3.12A

WASHINGTON D.C. UNDERGROUND VAULT SAND FILTER
(WET SEDIMENTATION CHAMBER)

Definition

A Washington D.C. vault sand filter is an underground stormwater sand filter contained in a structural shell with three chambers. The shell may be either precast or cast-in-place concrete, corrugated metal pipe, or fiberglass tanks. This BMP was developed by Mr. Hung V. Truong of the D.C. Environmental Regulation Administration. **Figure 3.12A-1** depicts Mr. Truong's system.

The three feet deep plunge pool in the first chamber and the throat of the second chamber, which are hydraulically connected by an underwater rectangular opening, absorbs energy and provides pretreatment, trapping grit and floating organic material such as oil, grease, and tree leaves.

The second chamber also contains a typical intermittent sand filter. The filter material consists of gravel, sand, and filter fabric. At the bottom is a subsurface drainage system of pierced PVC pipe in a gravel bed. The primary filter media is 18-24 inches of sand. A layer of plastic reinforced geotextile filter cloth secured by gravel ballast is placed on top of the sand. The top filter cloth is a pre-planned failure plane which can readily be replaced when the filter surface becomes clogged. A dewatering drain controlled by a gate valve must be installed to facilitate maintenance.

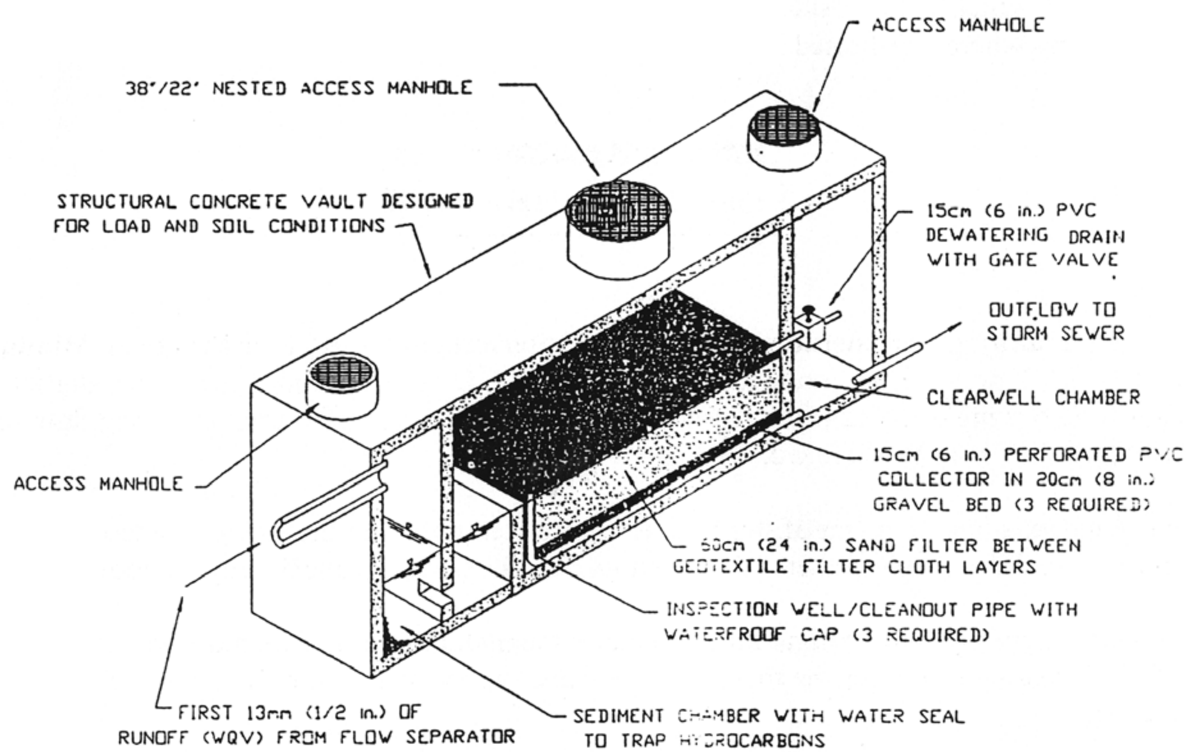
The third chamber, or clearwell, collects the flow from the underdrain pipes and directs it to the storm sewer.

In Virginia, D.C. Sand Filters will normally be placed off-line and be sized to treat the WQV.

Purpose

D.C. Sand Filters are primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity must be provided.

FIGURE 3.12A - 1
Washington D.C. Underground Vault Sand Filter



Conditions Where Practice Applies

D.C. Sand Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. Where possible, runoff treated should come only from impervious surfaces.

<u>Drainage Area</u>

Drainage areas served by one vault filter should be limited to 1.25 acres. For larger drainage sheds, either multiple vault filters or Austin Full Sedimentation Filters (surface or vault) should be utilized.

Development Conditions

D.C. Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

Planning Considerations

Refer to the **Planning Considerations** for **General Intermittent Sand Filter Practices, Minimum Standard 3.12,** previously discussed in this section. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration (whatever the pooling depth, there must be a minimum of five feet of clearance between the top of the filter and the top slab of the filter shell to allow filter maintenance).

Sand filter BMPS must ***never*** *be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of D.C. Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

The D.C. Sand Filter is a partial sedimentation protection intermittent sand filter BMP. To compute the minimum area of filter required, utilize the Austin Filter Formula for partial sedimentation treatment:

$$A_{fm(PS)} = \frac{545 I_a d_f}{(h + d_f)}$$

where,

A_{fm} = minimum surface area of sand bed (square feet)
I_a = impervious cover on the watershed in acres
d_f = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

Structural Requirements

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and, certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer and the structural plans require approval by the plan approving jurisdiction.

Design Storm

The inlet design or integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. Since D.C. Sand Filters will be used only as off-line facilities in Virginia, the interior hydraulics of the filter are not as critical as when used as an on-line facility. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable that D.C. Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

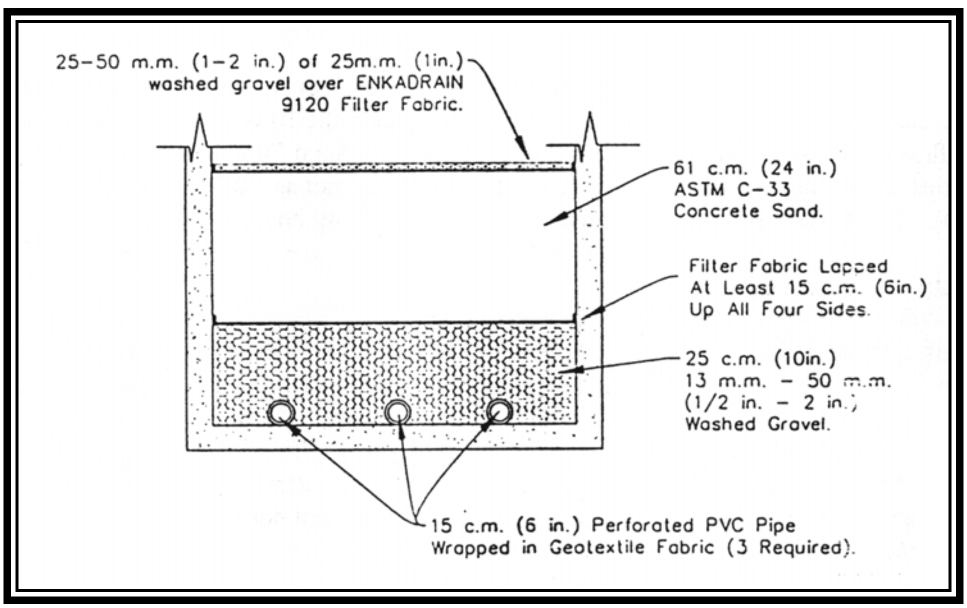
Accessibility and Headroom for Maintenance

Both the sedimentation basin and the filter must be accessible to approriate equipment and vacuum trucks for removing accumulated sediments and trash. The sedimentation basin must be cleaned approximately once per year, and the filter will likely need raking on that frequency to remove trash and restore permeability. When filters are placed in underground vaults, all three chambers must have personnel access manholes and built-in access ladders. **A minimum headspace of 60 inches above the filter is required to allow such maintenance and repair.** A 38-inch diameter maintenance manhole with eccentric nested covers (a 22-inch personnel access lid inside the 38-inch diameter lid) or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter.

Construction Specifications

Figure 3.12A-2 is a cross-section of the filter chamber.

FIGURE 3.12A - 2
D.C. Sand Filter Cross-Section



Depth of Sedimantation Pool

The sedimentation “plunge pool” must be at least 36 inches deep to properly remove sediment and absorb energy from the incoming flow.

Depth of the Underwater Opening Between Chambers

To preserve an effective hydrocarbon trap, the top of the underwater opening between chambers must be at least 18 inches below the depth of the weir which divides the filter from the pool. To retain sediment in the first chamber, the bottom of the opening should be at least six inches above the floor. The area of the opening should be at least 1.5 times the cross-sectional area of the inflow pipe(s) to assure that the water level remains equal between the first and second chambers.

Total Depth of Filter Cross-Section

The total depth of the filter cross-section must match the height of the weir dividing the sedimentation pool from the filter. Otherwise, a “waterfall” effect will develop which will gouge out the front of the filter media. If a sand filter less than 24 inches is used, the gravel layer must be increased accordingly to preserve the overall filter depth.

Upper Aggregate Layer

The washed aggregate or gravel layer at the top of the filter shall be at least one inch thick and meet ASTM standard specifications (1-inch maximum diameter).

Geotextile Fabrics

The filter cloth layer beneath the upper aggregate layer shall be reinforced by an HDPE or PVC geomatrix (such as ENKADRAIN 9120) and meet the specifications shown in **Table 3.12C-1**. The filter fabric between the sand layer and the collector gravel shall conform to the specifications in **Table 3.12A-2**. The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand** or sand meeting the Grade A fine aggregate gradation standards of Section 202 of the VDOT ***Road and Bridge Specifications.*** The top of the sand filter must be completely level.

TABLE 3.12A - 1
Specifications for Nonwoven Geotextile Fabric on Top of D.C. Sand Filter

Property	Test Method	Unit	Specification
Unit Weight	ASTM D-1777	Oz./Sq.yd.	4.3 (minimum)
Flow Rate	Falling Head Test	Gpm/Sq.ft.	120 (minimum)
Puncture Strength	ASTM D-751 (Modified)	Lb.	60 (minimum)
Thickness	--	In.	0.08 (minimum)

Table 3.12A - 2
Specifications for Nonwoven Geotextile Fabric Beneath Sand in D.C. Filter

Property	Test Method	Unit	Specification
Unit Weight	--	Oz./sq.yd.	8.0 (min.)
Filtration Rate	--	In/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (min.)
Mullen Burst Strength	ASTM D-751	Psi	400 (min.)
Equiv. Opening Size	U.S. Standard Sieve	No.	80 (min.)
Tensile Strength	ASTM D-1682	Lb.	300 (min.)

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes.

Underdrain Piping

The underdrain piping consists of three 6-inch schedule 40 or better polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations should be 3/8 inch, and each row of perforations shall contain at least six (6) holes. Maximum spacing between rows of perforations shall be six (6) inches.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface, e.g. the top layer of gravel.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12A-2** above.

Dewatering Drain

When the filter is placed in an underground vault, A 6-inch dewatering drain controlled by a gate valve shall be installed between the filter chamber and the clearwell chamber with its invert at the elevation of the top of the filter. The dewatering drain penetration in the chamber dividing wall shall be sealed with a flexible strip joint sealant which swells in contact with water to form a tight pressure seal.

Access Manholes

When the filter is installed in an underground vault, access to the headbox (sediment chamber) and the clearwell shall be provided through at least 22-inch manholes. Access to the filter chamber shall be provided by a rectangular dood (minimum size: 4 feet by four feet) of sufficient strength to carry prospective imposed loads or by a manhole of at least 3- inch diameter with an offset concentric 22-inch lid (Neenah R-1741-D or equivalent).

Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation. Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

After completion of the filter shell but before placement of the filter layers, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

After placement of the collector pipes, gravel, and lower geotextile layer, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

Portland Cement Concrete

Concrete liners may be used for sedimentation chambers and for sedimentation and filtration basins. Concrete shall be at least five (5) inch thick Class A3 defined in the Virginia Department of Transportation *Road and Bridge Specifications.*

Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

The water level in the filter chamber shall be monitored by the owner on a quarterly basis and after every large storm for the first year after completion of construction and a log shall be maintained of the results indicating the rate of dewatering after each storm and the water depth for each observation. Once the governing jurisdiction staff indicates that satisfactory performance of the structure has been demonstrated, the monitoring schedule can be reduced to an semiannual basis.

The BMP shall be inspected annually by representatives of the owner and the governing jurisdiction to assure continued proper functioning.

Sediment Chamber Pumpout

The sediment chamber must be pumped out halfway through the inspection cycle (e.g. after six months) and after each joint owner-governing jurisdiction annual inspection. If the chamber contains an oil skim, it should be removed by a firm specializing in oil recovery and recycling. The remaining material may then be removed by vacuum pump and disposed of in an appropriate landfill. **After each cleaning, refill the first chamber to a depth of three feet with clean water to reestablish the water seals**.

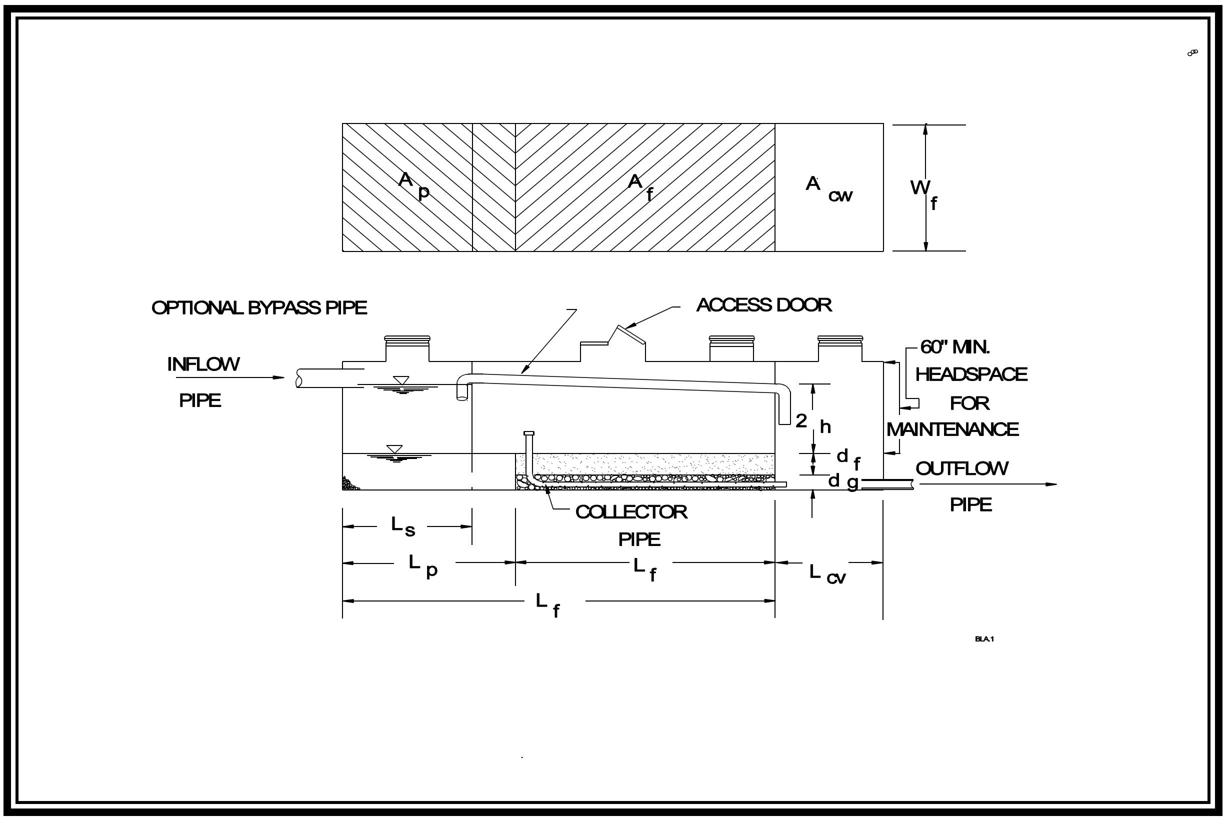
When the filter will no longer draw down within the required 40-hour period, the top layer of filter cloth and ballast gravel must be removed and replaced with new materials conforming to the original specifications. Any discolored or sediment contaminated sand shall also be removed and replaced.

Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by the D.C.Sand Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used.

Figure 3.12A-3 shows the dimensional relationships for a D.C. Sand Filter.

FIGURE 3.12A - 3
Dimensional Relationships for a D.C. Sand Filter



Standard Design Logic

Employ the following design logic to design D.C. Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site (I_a in acres), the water quality volume to be treated (WQV in ft.^{3} = 1816 I_a), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth ((d_f) and determine the maximum achievable ponding depth over the filter (2h).

3. Compute the Minimum Area of the Sand Filter (A_{fm})

To compute the area of the filter, use the formula:

$$A_{fmPS} = \frac{545 I_a d_f}{(h + d_f)}$$

A_{fm} = minimum surface area of sand bed (square feet)
I_a = impervious cover on the watershed in acres
d_f = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

4. Select Filter Width and Compute Filter Length and Adjusted Filter Area

Considering site constraints, select the Filter Width (W_f). Then compute the Filter Length (L_f) and the Adjusted Filter Area (A_f)

$$L_f = A_{fm}/W_f$$

$$A_f = W_f \times L_f$$

Note: From this point forward, computations assume a rectangular filter.

5. Compute the Storage Volume on Top of the Filter (V_{Tf})

$$V_{Tf} = A_f \times 2h$$

6. Compute the Storage in the Filter Voids (V_v)
   (Assume 40% voids in filter media)

$$V_v = 0.4 \times A_f \times (d_f + d_g)$$

7. Compute Flow Through Filter During Filling (V_Q)
   (Assume 1-hour to fill per D.C. practice)

$$V_Q = \frac{kA_f(d_f + h)}{d_f} \text{ ; use } k = 2 \text{ ft./day} = 0.0833/\text{hr.}$$

8. Compute Net Volume to be Stored Awaiting Filtration (V_{st})

$$V_{st} = WQV - V_{Tf} - V_v - V_Q$$

9. Compute Length of the Permanent Pool (Lpm)

$$Lpm \quad \frac{V_{st}}{(2h \times W_f)}$$

10. Compute Minimum Length of the Sediment Chamber (Lsc)
    (to contain 20% of WQV per Austin practice)

$$L_{sm} = \frac{0.2WQV}{(2h \times W_f)}$$

11. Set Final Length of the Permanent Pool (L_p)

If $L_{pm} \geq L_{sm} + 2$ ft., make $L_p = L_{pm}$

If $L_{pm} < L_{sm} + 2$ ft., make $L_p = L_{sm + 2\text{ ft.}}$

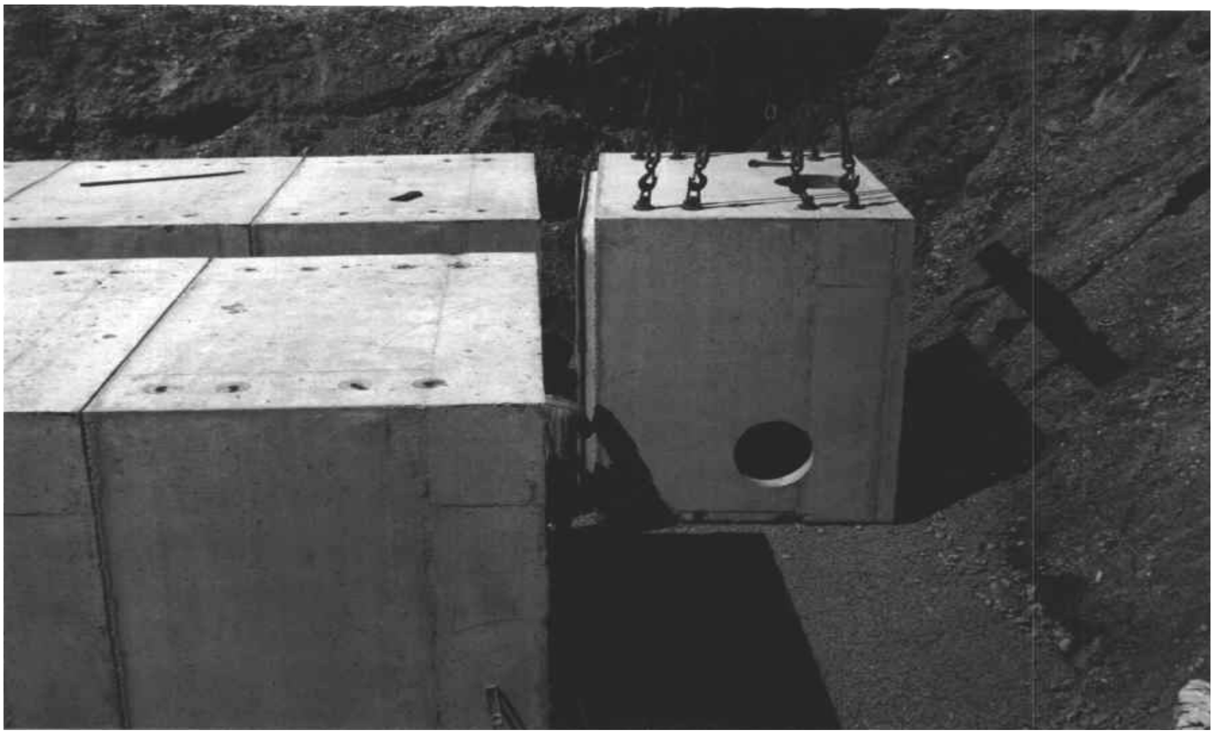
It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

Set the length of the clearwell (L_{cw}) for adequate maintenance and/or access for monitoring flow rate and chemical composition of the effluent (minimum = 3 ft.)

Minimizing Filter Shell Costs

Underground vault sand filter costs have been widely varying because many developers have simply had their foundation contractors cast the vault in place. Each installation therefore became a prototype with associated costs and overhead. Precast manufacturers currently offer precasting services for D.C. and other types of sand filter vaults, which should stabilize underground vault costs. **Figure 3.12A-4** is a photograph of a segmented precast filter shell installation in Alexandria.

FIGURE 3.12A - 4
Installing Precast D.C. Sand Filter Shell in Alexandria

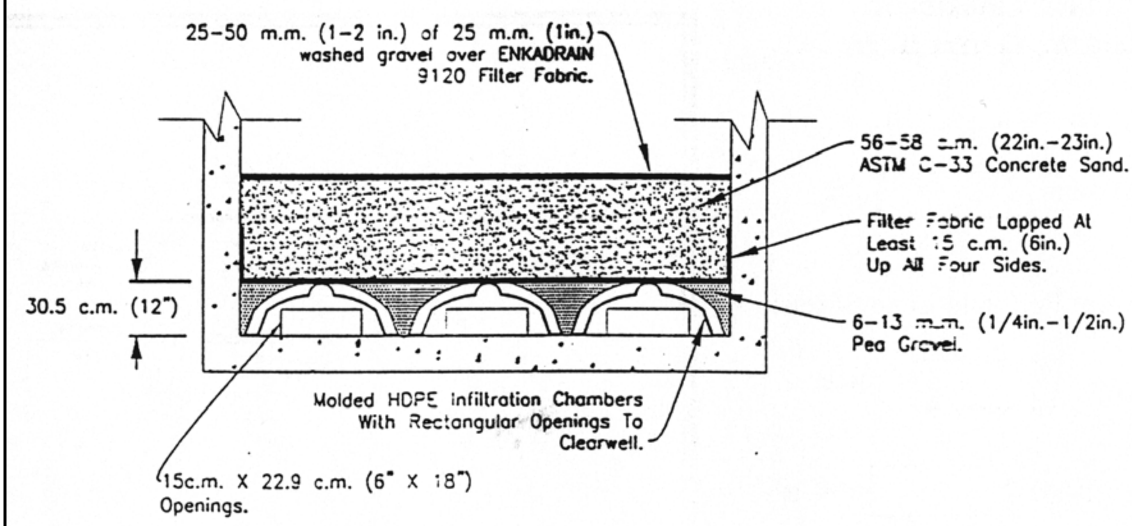


(Photo Courtesy of Rotondo Precast, Fredericksburg, Virginia)

Checklists

Worksheet 3.12A is for use in sizing calculations for D.C. Sand Filters. The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

FIGURE 3.12A - 5
D.C. Filter Cross-Section with HDPE Infiltration Chamber Collector System

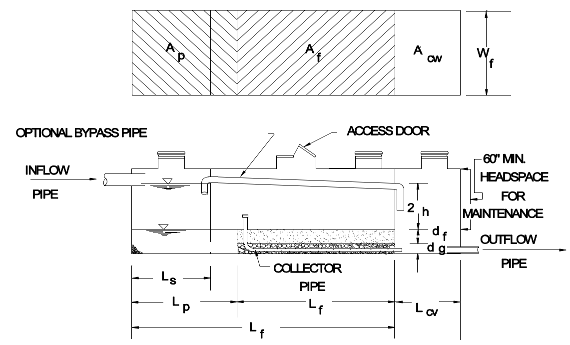


WORKSHEET 3.12A
SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER
Page 1 of 4

Part 1: Select maximum ponding depth over filter:

2h = _______ ft;

h = [ ] ft



From Pollutant Load Sheets:

I_a = [ ] acres

WQV = [ ] ft^3

Outflow by gravity possible ___

Effluent pump required __

Part 2: Compute Minimum Area of Filter (A_{fm}):

$$A_{fm} = \frac{545 I_a d_f}{(d_f + h)}$$

= [545 x _______ x _______] / [_______ + _______]

= [ ] ft^2

Part3: Considering Site Constraints, Select Filter Width (W_f) and Compute Filter Length (L_f) and Adjusted Filter Area (A_f):

W_f = [ ] ft;

WORKSHEET 3.12A
SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER
Page 2 of 4

$L_f = A_{fm} / W_f$

$= \_\_\_\_\_\_\_\_ / \_\_\_\_\_\_\_\_$

$= \_\_\_\_\_\_$, say $\boxed{}$ ft

$A_f = W_f \times L_f = \_\_\_\_\_\_\_\_ \times \_\_\_\_\_\_\_\_\_$

$= \boxed{}$ ft^2

Part 4: Compute the Storage Volume on Top of the Filter(V_{Tf})

$V_{Tf} = A_f \times 2h = \_\_\_\_\_\_\_\_ \times \_\_\_\_\_\_\_\_\_$

$= \boxed{}$ ft^3

Part 5: Compute Storage in Filter Voids (V_v):
(Assume 40% voids in filter media)

$V_v = 0.4 \times A_f \times (d_f + d_g)$

$= 0.4 \times \_\_\_\_\_\_\_\_ \times (\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_)$

$= \boxed{}$ ft^3

Part 6: Compute Flow Through Filter During Filling Period (V_Q):
(Assume 1-hour to fill per D.C. practice)

$V_Q = \frac{kA_f(d_f + h)}{d_f}$; use k = 2 ft/day = 0.0833 ft/hr

$= [0.0833 \times \_\_\_\_\_\_\_\_ \times (\_\_\_\_\_\_\_\_\_ + \_\_\_\_\_\_\_\_)]/\_\_\_\_\_\_\_\_\_\_$

$= \boxed{}$ ft^3

WORKSHEET 3.12A
SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER
Page 3 of 4

Part 7: Compute Net Volume to be Stored Awaiting Filtration (V_{st}):

$V_{st} = WQV - V_{Tf} - V_v - V_Q$

= _______ - _______ - _______ - _______

= [ ] ft^3

Part 8: Compute Minimum Length of Permanent Pool (L_{pm}):

$L_{pm} = \dfrac{V_{st}}{(2h \times W_f)}$ = _______ / (_______ x _______)

= [ ] ft

Part 9: Compute Minimum Length of Sediment Chamber (L_{sm})
(to contain at least 20% of WQV per Austin practice)

$L_{sm} = \dfrac{0.2WQV}{(2h \times W_f)}$ = _______ /_______

= [ ] ft

Part 10: Set Final Length of Permanent Pool (L_p)

L_{sm} + 2ft = ________ + 2 = [ ] ft

If $L_{pm} \geq L_{sm}$ + 2ft, Make $L_p = L_{pm}$ [ ] = ft

If $L_{pm} < L_{sm}$ + 2ft, make $L_p = L_{sm}$ +2ft = [ ]

WORKSHEET 3.12A
SIZING COMPUTATIONS FOR D.C. UNDERGROUND VAULT SAND FILTER
Page 4 of 4

Part 11: Set Length of Clearwell (L_{cw}) for Adequate Maintenance Access (Minimum = 3 ft) and Compute Final Inside Length (L_{ti}):

L_{cw} = [ ] ft;

Sum of interior partition thicknesses (t_{pi}) = ________ ft

$L_{ti} = L_f + L_p + L_{cw} + t_{pi}$

= ________ + ________ + ________ + ________

= [ ] ft

Part 12: Design Effluent Pump if Required

Since pump must be capable of handling flow when filter is new, use k = 12 feet/day = 0.5 ft/hr

$$Q = \frac{kA_f(d_f + h)}{d_f}$$

= [0.5 x ________ x (________ + ________)] /________

= [ ] ft^3/hr ; /3600 = [ ] cfs;

x 448 = [ ] gpm

Part 13: Design Structural Shell to Accommodate Soil and Load conditions at Site:

It may be economical to adjust final dimensions upward to correspond with standard precast structures or to round dimensions upward to simplify layout during construction.

MINIMUM STANDARD 3.12B

DELAWARE SAND FILTER (DSF) SYSTEMS

Definition

Mr. Earl Shaver of the Delaware Department of Natural Resources and Environmental Control has developed a surface sand filter system for use in Delaware (Shaver and Baldwin, 1991)

As originally conceived, the Delaware Sand Filter is an **on-line** facility processing all stormwater exiting the treated site up to the point that its overflow limit is reached (Delaware provides for treating the first one inch of runoff). However, when employed in Virginia, it will usually be provided with an integral flow-splitter to isolate and treat the Water Quality Volume.

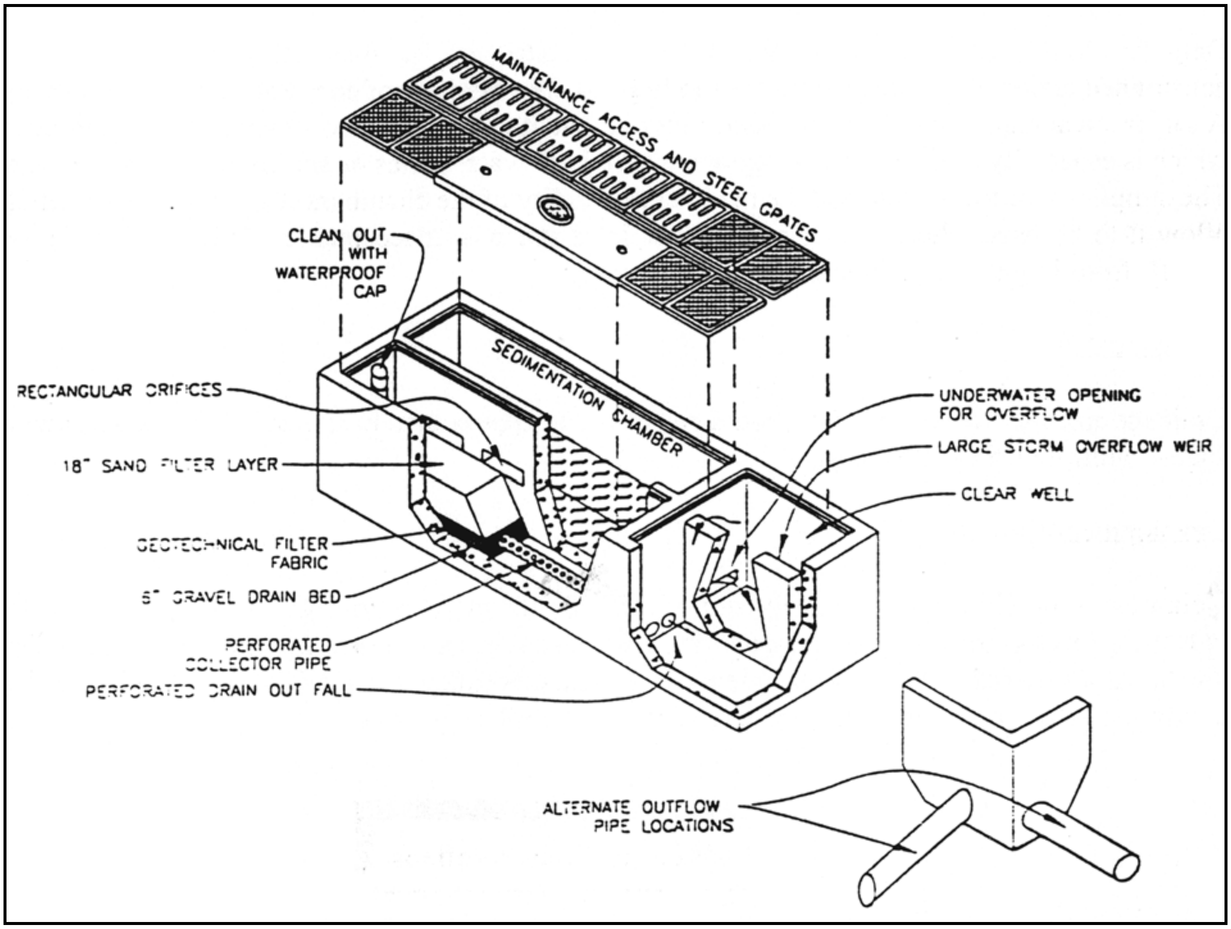
Figure 3.12B-1 shows a schematic drawing of the Delaware Sand Filter as used in Virginia. The system consists of two parallel concrete trenches connected by close-spaced wide notches in the wall dividing the trenches. The trench adjacent to the site being served is the sedimentation chamber. When accepting sheet flow, it is fitted with a grated cover. Concentrated stormwater may also be conveyed to the chamber in enclosed storm drain pipes. The second chamber, which contains the sand filter, is always fitted with a solid cover.

Storm flows enter the sedimentation chamber through the grates, causing the sedimentation pool to rise and overflow into the filter chamber through the weir notches in the dividing wall, assuring that the water to be treated **arrives at the filter as sheet flow**. This is essential to prevent scouring out the sand. The permanent pool in the sedimentation chamber is dead storage, which inhibits resuspension of particles that were deposited in earlier storms and prevents the heavier sediments from being washed into the filter chamber. Floatable materials and hydrocarbon films, however, may reach the filter media through the surface outflow.

The second trench contains at least 18 inches of ASTM C-33 Concrete Sand . When used in Virginia, an underdrain capability must be provided. Runoff percolates through the sand to the underdrain (s) and exits into the flow splitter/clearwell.

A transverse flow-splitter/clearwell at the lower end of the structure collects treated effluent and overflow and conveys the water to the storm sewer. When the filter shell fills with the Water Quality Volume, excess flow is forced through the underwater opening from the sedimentation chamber to the “wet” section of the clearwell to overflow the weir to the outflow pipe chamber. Floating trash and hydrocarbons are retained in the sedimentation chamber by this “trap.”

FIGURE 3.12B - 1
Precast Delaware Sand Filter as Used in Virginia



Purpose

Delaware Sand Filters primarily used for water quality control. However, they do provide detention and slow release of the water quality volume from the site being treated. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon site conditions (hydrology) and required discharge reductions. The 10-year and 100-year flows will usually exceed the detention capacity of a sand media filter. When this occurs, separate quantity must be provided.

Conditions Where Practice Applies

Delaware Sand Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. A major advantage of the Delaware Sand Filter is that it can be installed in shallow configurations, which is especially critical in flatter regions where high water tables or shallow storm sewers exist. The simplicity of the system and the ready accessibility of the chambers for periodic maintenance allow it to be used where a filter built in confined space is unacceptable. Where possible, only runoff from impervious surfaces should be treated.

Drainage Area

Drainage areas served by one filter should be limited to approximately one acre. For larger drainage sheds, multiple DSFs may be used.

Development Conditions

Delaware Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

Planning Considerations

Refer to the **Planning Considerations** for **General Intermittent Sand Filter Practices, Minimum Standard 3.12,** previously discussed in this section. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration.

Sand filter BMPS must ***never*** *be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of Delaware Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

Because of the shallow configuration of this BMP, resulting in low levels of hydraulic head above the filter, application of the usual partial sedimentation filter formula may not create enough storage volume to contain the WQV. With the dimensional relationships shown in **Figure 3.12B-2** and k = 2.0 ft/day, the required DSF filter area to contain the WQV may be written as follows:

$$A_f = \frac{1816 I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

where:

A_f = the **area of the filter** in sq.ft.
I_a = the impervious area on the watershed in acres
h = 1/2 the maximum ponding depth over the filter (ft.)

If the maximum ponding depth above the filter (2h) is less than 2.67 feet (2'-8"), the WQV storage requirement governs and the above foumula must be used to size the filter (Alexandria, 1992). If the the maximum ponding depth above the filter (2h) is 2.67 feet or greater, use the partial sedimentation filter formula:

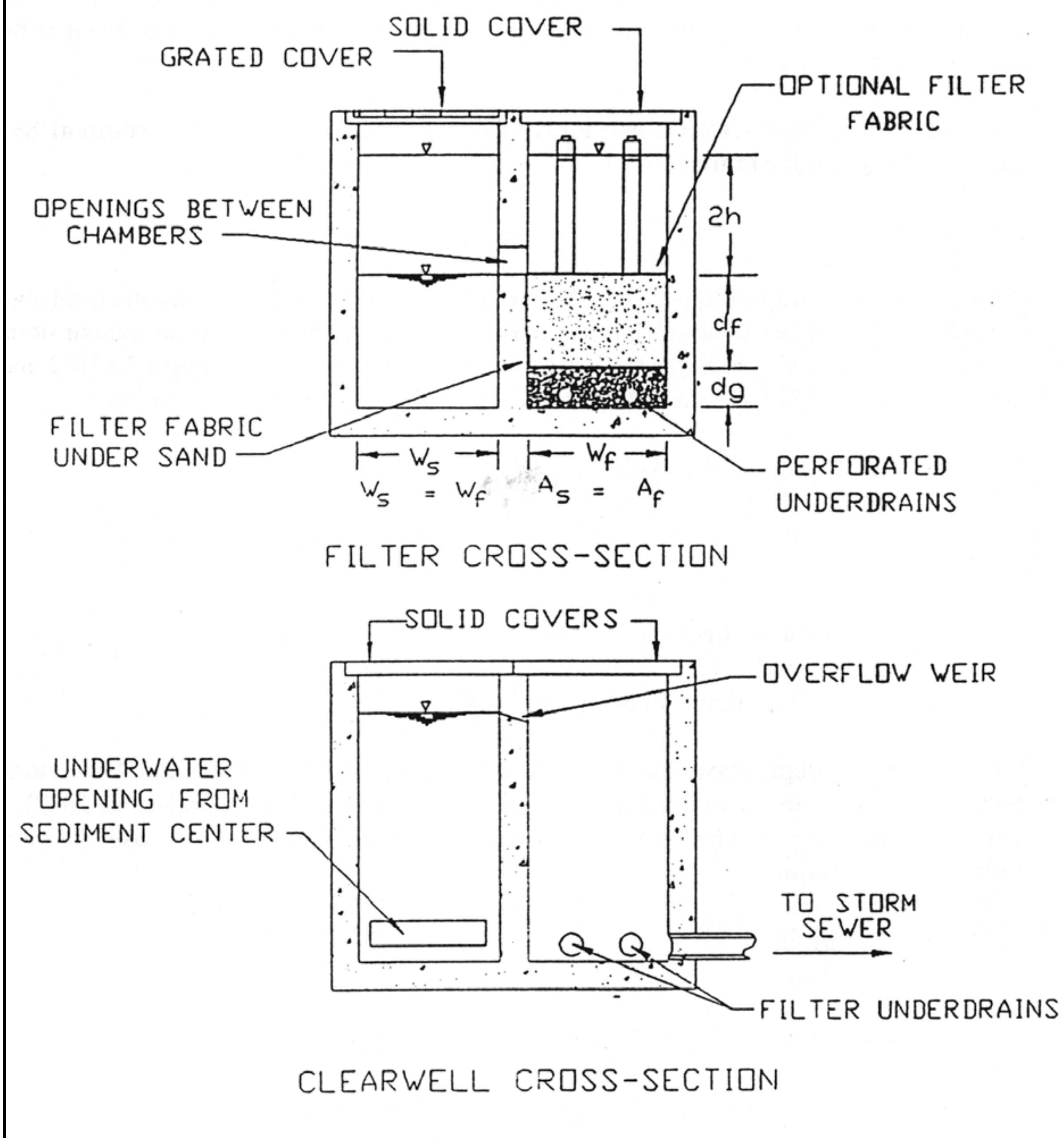
$$A_f = \frac{545 I_a d_f}{(h + d_f)}$$

Where d_f = depth of the filter media in ft. (1.5-2.0)

Delaware and Virginia make the area of the sediment chamber(A_s) equal the area of the filter:

$$A_f = A_s$$

FIGURE 3.12B- 2
Dimensional Relationships for Delaware Sand Filter



Structural Requirements

When the system is placed in a street or parking lot, it must be designed to support traffic wheel loads. When placed completely off the pavement, lower structural loads will be involved. The structure must be designed by a licensed professional engineer, and the design must be approved by the governing jurisdiction.

Design Storm

The inlet integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable that Delaware Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

Construction Specifications

Upper Aggregate Layer

Some jurisdictions require a layer of filter cloth and gravel on top of the filter. When used, the washed aggregate or gravel layer at the top of the filter shall be one inch thick and meet ASTM standard specifications (1 inch maximum diameter.)

Geotextile Fabrics

When used, the filter fabric beneath the one-inch layer of gravel on top of the filter shall be Enkadrain 9120 filter fabric or equivalent with the specifications shown in **Table 3.12B - 1**.

Table 3.12B - 1
Specifications for Nonwoven Geotextile Fabric on Top of Delaware Sand Filter

Property	Test Method	Unit	Specification
Unit Weight	ASTM D-1777	Oz./sq.yd.	4.3 (min.)
Flow Rate	Falling Head Test	Gpm/sq.ft.	120 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	60 (min.)
Thickness	--	In.	0.8 (min.)

In instances where heavy hydrocarbon loadings are expected, a layer of activated carbon impregnated filter fabric such as Enkadrain PF-3 may be advantageous. When used, a plan to dispose of the hydrocarbon laden used filter fabric must be approved by the applicable jurisdiction prior to placing the sand filter in service.

The filter cloth layer beneath the sand shall conform to the specifications shown in **Table 3.12B-2**.

Table 3.12B - 2
Specifications for Nonwoven Geotextile Fabric Beneath Sand in Delaware Sand Filter

Property	Test Method	Unit	Specification
Unit Weight	--	Oz./sq.yd.	8.0 (min.)
Filtration Rate	--	In/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (min.)
Mullen Burst Strength	ASTM D-751	Psi	400 (min.)
Equiv. Opening Size	U.S. Standard Sieve	No.	80 (min.)
Tensile Strength	ASTM D-1682	Lb.	300 (min.)

The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand.** The top of the sand filter must be completely level. No grade is allowable.

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes. The gravel and the sand layer above must be separated by a layer of geotextile fabric meeting the specification listed above.

Underdrain Piping

When round perforated pipes are used, the underdrain piping shall consist of a minimum of two (2) schedule 40 or better four (4) inch polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations shall be 3/8 inch, and each row of perforations shall contain at least four (4) holes. Maximum spacing between rows of perforations shall be six (6) inches.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12B - 2** above.

Alternative Underdrains

Shallow rectangular drain tiles may be fabricated from such materials as fiberglass structural channels, saving several inches of filter depth. Drain tiles shall normally be in two-foot lengths and spaced to provide gaps 1/8-inch less than the smallest gravel sizes on all four sides. Sections of tile may be cast in the dividing wall between the filter and the clearwell to provide shallow outflow oricices. Flat perforated drainage piping such as AdvantEdge® may also be used to reduce the depth of filter. Another approach is to raise a grate on small masonary units above the floor of the shell, lay a layer of PVC or polyethelene geomatrix on the grate to spread the load, and install the filter cloth and sand above this matting; molded HDPE infiltration chambers may also be used as shown in **Figure 3.12A-5.** The entire bottom of the filter shell thus becomes a collector channel. When the shell bottom is so used, it shall have a minimum slope of 1/8 inch per foot (1%).

Weepholes

In addition to the underdrain pipes, weepholes may be installed between the filter chamber and the clearwell to provide relief in case of pipe clogging. The weepholes shall be three (3) inches in diameter. Minimum spacing shall be nine (9) inches center to center. The openings on the filter side of the dividing wall shall be covered to the width of the trench with 12 inch high plastic hardware cloth of 1/4 inch mesh or galvanized steel wire, minimum wire diameter 0.03-inch, number 4 mesh hardware cloth anchored firmly to the dividing wall structure and folded a minimum of 6 inches back under the bottom stone.

Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation. Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

After completion of the filter shell but before placement of the filter layers, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

After placement of the collector pipes, gravel, and lower geotextile layer, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

Grates and Covers

When placed in traffic lanes, grates and covers must withstand H-20 wheelloadings. Use of standard Virginia Department of Transportation (VDOT) grates (Grate D1-1) will often be most cost-effective. Where allowed by local jurisdictions, galvanized steel bar grates are economical.

Portland Cement Concrete

Portland Cement concrete used for the trench structure shall conform to the A3 specification of the Virginia Department of Transportation ***Road and Bridge Specifications***, latest edition.

Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Inspection Schedule

During the first year of operation, the cover grates or precast lids on the chambers must be removed quarterly and a joint owner-jurisdiction inspection made to assure that the system is functioning. Once the jurisdiction inspectors are satisfied that the system is functioning properly, this inspection may be made on an annual basis for other than auto-related activities.

Sediment Chamber Pumpout

The sediment chamber must be pumped out when the joint owner-jurisdiction determines that . If the chamber contains an oil skim, it should be removed by a firm specializing in oil recovery and recycling. The remaining material may then be removed by vacuum pump and disposed of in an appropriate landfill. **After each cleaning, refill the first chamber with clean water to reestablish the water seals to the clearwell.**

Sand Filter

When deposition of sediments in the filtration chamber indicate that the filter media is clogging and not performing properly, sediments must be removed (a small shovel may be all that is necessary) along with the top two to three inches of sand. The coloration of the sand will provide a good indication of what depth of removal is required. Clean sand must then be placed in the filter to restore the design depth. Where a layer of geotechnical fabric overlays the filter, the fabric shall be rolled up and removed and a similar layer of clean fabric installed. Any discolored sand shall also be removed and replaced. Disposal of petroleum hydrocarbon contaminated sand or filter cloth should be coordinated with the appropriate environmental official of the local jurisdiction. On filters which employ an upper geotextile layer and ballast, the top layer of filter cloth and ballast gravel must be removed and replaced with new materials conforming to the original specifications when the filter will no longer draw down within the required 40-hour period. Any discolored or sediment contaminated sand shall also be removed and replaced with sand meeting the original specifications (ASTM C-33 Concrete Sand).

Concrete Shell Inspection

Concrete will deteriorate over time, especially if subjected to live loads. The concrete shell, risers, etc., must be examined during each annual inspection to identify areas that are in need of repair, and such repairs must be promptly effected.

Grass Clippings

Grass clippings from landscape areas on the drainage watershed flowing into the DSF must be bagged and removed from the site to prevent them washing into and contaminating the sediment chamber and filter.

Trash Collection

Trash collected on the grates protecting the inlets shall be removed no less frequently than weekly to assure preserving the inflow capacity of the BMP.

Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by the Delaware Sand Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used. **Figure 3.12B-2** shows the dimensional relationships required to compute the design.

Standard Design Logic

Employ the following design logic to design Delaware Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site (I_a in acres), the water quality volume to be treated (WQV in $ft.^3 = 1816\ I_a$), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth ((d_f) and determine the maximum achievable ponding depth over the filter (2h).

3. Calculate the Required Surface Areas of the Chambers

If the maximum ponding depth above the filter (2h) is less than 2.67 feet (2'-8"), the WQV storage requirement governs and the above foumula must be used:

$$A_f = \frac{1816 I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

where:

A_f = the **area of the filter** in sq.ft.

I_a = the impervious area on the watershed in acres

h = 1/2 the maximum ponding depth over the filter (ft.)

If the the maximum ponding depth above the filter (2h) is 2.67 feet or greater, use the partial sedimentation filter formula:

$$A_f = \frac{545 I_a d_f}{(h + d_f)}$$

where:

d_f = depth of the filter media in ft. (1.5-2.0)

Delaware and Virginia make the area of the filter equal the area of the sediment chamber:

$A_f = A_s$

4. Establish Dimensions of the Facility

Site considerations usually dictate the final dimensions of the facility. Sediment trenches and filter trenches normally be 18-30 inches wide. Use of standard VDOT D1-1 grates requires a trench width of 26". Some jurisdictions restrict the maximum allowable trench width to 36 inches.

Minimizing Filter Shell Costs

Underground vault sand filter costs have been widely varying because many developers have simply had their foundation contractors cast the vault in place. Each installation therefore became a prototype with associated costs and overhead. Precast manufacturers currently offer precasting services for D.C. and other types of sand filter vaults, which should stabilize underground vault costs. **Figure 3.12B3** is a photograph of a segmented precast shell installation in Alexandria.

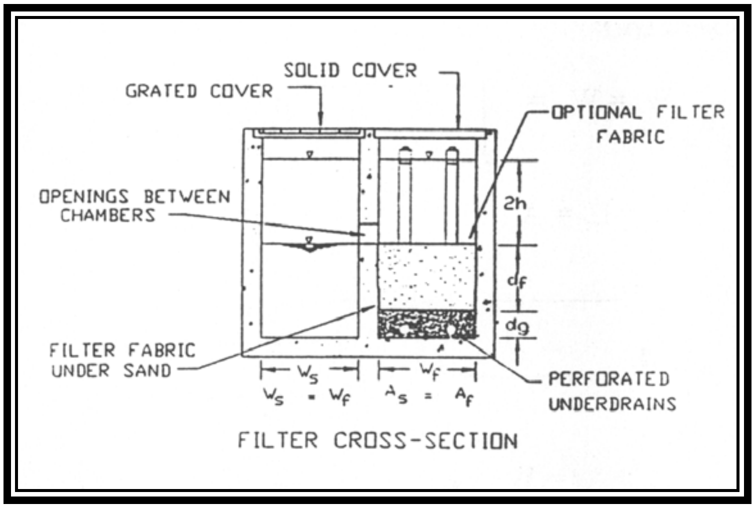
FIGURE 3.12B - 3
Installing Precast Delaware Sand Filter Shell in Alexandria, Virginia

(Photo Courtesy of Rotondo Precast, Fredericksburg, Virginia)

Checklists

Worksheet 3.12B is for use in sizing calculations for Delaware Sand Filters. The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

WORKSHEET 3.12B
SIZING COMPUTATIONS FOR STANDARD DELAWARE SAND FILTER
Page 1 of 2



Part 1: Select maximum ponding depth over filter:

2h = _______ft;

h = [   ] ft

From Pollutant Load Sheets:

I_a = [   ] acres

WQV = [   ] ft^3

Outflow by gravity possible____; Effluent pump required _____

Part 2: Compute Minimum Area of Filter (A_{fm}) and Sediment Pool (A_{sm}):

a) If 2h ≥ 2.67 feet, use the formula:

$$A_{sm} = A_{fm} = \frac{545 I_a d_f}{(d_f + h)}$$

= [545 x ______ x ______] / [______ + ______]

= [   ] ft^2

b) If 2h < 2.67 feet, use the formula:

$$A_{sm} = A_{fm} = \frac{1816\ I_a}{(4.1h + 0.9)} = \frac{WQV}{(4.1h + 0.9)}$$

= ________ / [(4.1 x ________) + 0.9]

= [   ] ft^2

WORKSHEET 3.12B
SIZING COMPUTATIONS FOR STANDARD DELAWARE SAND FILTER
Page 2 of 2

Part 3: Considering Site Constraints, Select Filter Width (W_f) and Sediment Pool Width (W_s) and Compute Filter Length (L_f) and Adjusted Filter Area (A_f) and Sediment Chamber Area (A_s):

$W_s = W_f =$ $\boxed{}$ ft;

$L_s = L_f = A_{fm}/ W_f$

= _________ /_________

= __________, $\boxed{}$ say ft

$A_s = A_f = W_f \times L_f =$ _________ x _________

= $\boxed{}$ ft^2

Part 4: Design Structural Shell to accommodate Soil and Load Conditions at Site:

(Separate computations by a structural engineer).

Part 5: Design Effluent Pump if Required:

Since pump must be capable of handling flow when filter is new, use k = 12 feet/day = 0.5 ft/hr

$$Q = \frac{kA_f(d_f + h)}{d_f}$$

= [0.5 x _________ x (_________ + ________)]/__________

= $\boxed{}$ ft^3/hr ; /3600 $\boxed{}$ = cfs;

x 448 = $\boxed{}$ gpm

MINIMUM STANDARD 3.12C

AUSTIN SURFACE SAND FILTER SYSTEMS

Definition

The City of Austin, Texas, hase been using open basin intermittent sand filtration BMPs for treating stormwater runoff since the early 1980's. The Austin program is managed by the Environmental and Conservation Services Department, which has published design criteria in their *Environmental Criteria Manual* (Austin, 1988). Austin places heavy emphasis on pretreating the stormwater runoff in a sediment trapping presettling basin to protect the filter media from excessive sediment loading. The particles selected by Austin for complete removal in the full sedimentation protection basins are those which are greater than or equal in size to silt with a particle diameter of 0.00007 foot (20 microns) and a specific gravity of 2.65.

Figure 3.12C-1 illustrates an Austin Full Sedimantation Sand Filter application at a shopping center. In this system the sedimentation structure is a concrete basin designed to hold the entire WQV and then release it to the filtration basin over a 24-hour draw-down period. **Figure 3.12C-2** shows an alternative design which allows a smaller sedimentation chamber (20 percent of the WQV) while increasing the filter size to compensate for increased clogging of the filter media. Although the systems shown utilize concrete basins, a sediment pond and a geomembrane-lined filter built directly into he ground may be used where terrain and soil conditions allow.

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Purpose

Austin Sand Filters are used primarily for water quality control. However, they do provide detention and slow release over time of the WQV. Whether this amount will be sufficient to provide the necessary peak flow rate reductions required for channel erosion control is dependent upon the site conditions. However, in cases where quantity detention beyond the volume of the WQV is required, an attractive alternative may well be to utilize a combined detention basin/pre-settling basin configuration, with the controlled release of the entire stored volume to the sand filter facility.

FIGURE 3.12C - 1
Austin Full Sedimentation Sand Filter System at Barton Ridge Plaza

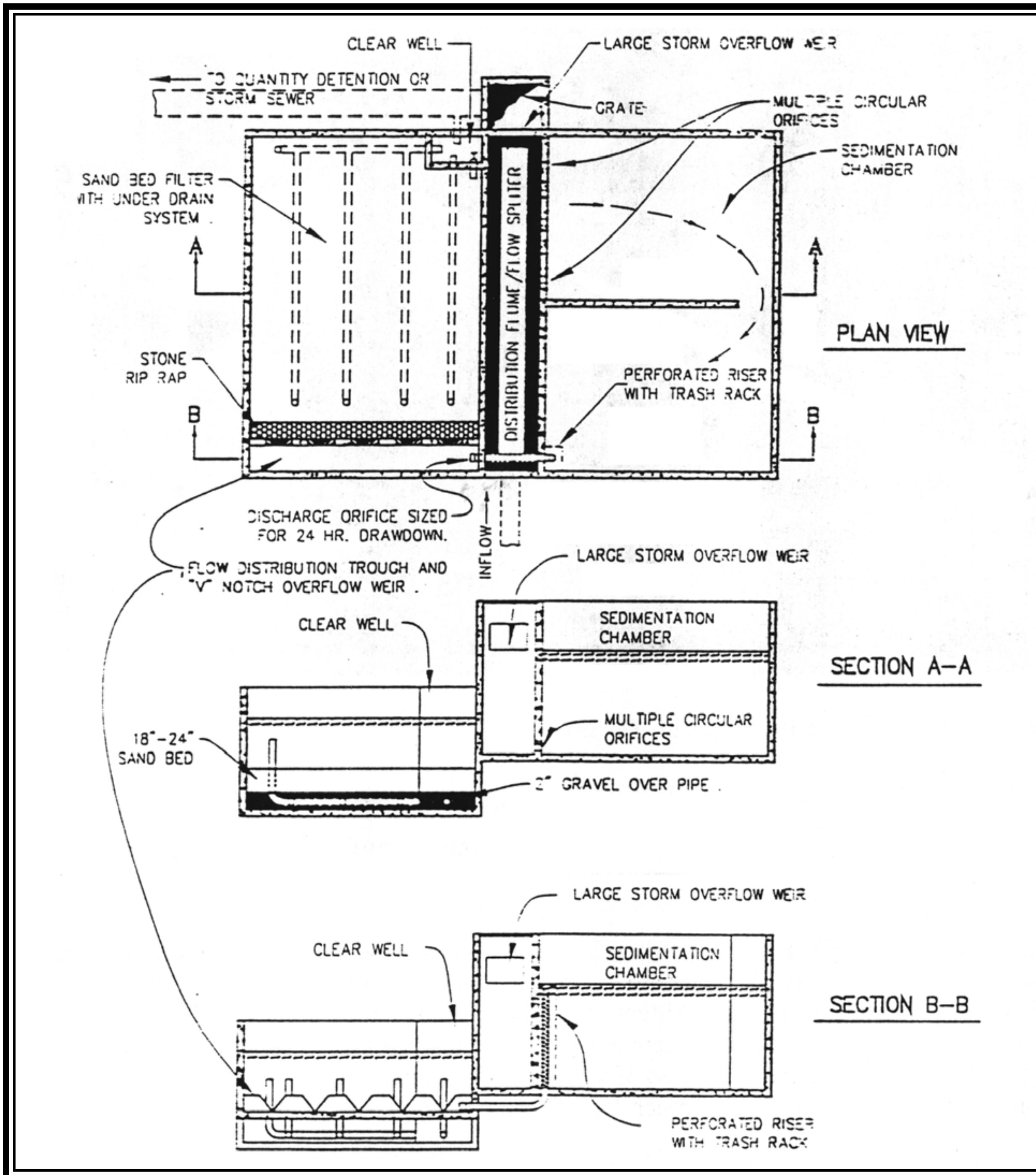


FIGURE 3.12C - 2
Sedimentation Basin of Jolleyville Partial Sedimentation System

(Poto Courtesy of the City of Austin, Texas)

Conditions Where Practice Applies

Austin Sand Filters Filters are ultra-urban BMPs best suited for use in situations where space is too constrained and/or real estate values are too high to allow the use of conventional retention ponds. Unlike D.C. and Delaware Sand Filters, when full sedimentation protection is provided, Austin filters may be used in situations where a higher amount of pervious surfaces are present or where higher sediment loads from deposition of wind-blown sediments are encountered. Because of their design, they may also be used on much larger drainage sheds.

Drainage Area

Austin full sedimentation and partial sedimentation basin sand filters have been used on drainage sheds up to 30 acres, and with great economy of scale. **Table 3.12-1** illustrates the relative costs of varying sized systems in Austin in mid-1990.

TABLE 3.12C - 1
Cost of Austin Sand Filtration Systems *(June 1990)*

Drainage Area (Acres)	Water Quality Volume (ft^3)	Cost/Acre ($/acre)	Cost/ft^3 ($/$ft^3$)	Total Cost ($)
1.0	1815	13,613* 19,058#	7.50* 10.50#	13,613* 19,058#
2.0	3,630	8,440* 9,801#	4.65* 5.40#	16,880* 19,602#
5.0	9,075	5,136	2.83	25,682
10.0	18,150	3,812	2.10	38,115
15.0	27,225	3,086	1.70	46,283
20.0	36,300	2,723	1.50	54,450
30.0	54,450	2.360	1.30	70,785

Footnotes:
* Calculated from data provided by Murfee Engineers
# Calculated from data provided by Austin Stormwater Management staff
All other values derived from combined data

While Austin has traditionally built these systems in open basins, there appears no reason why the basic designs cannot be adapted to underground vault construction where real estate values are high enough to justify their use. Austin Partial Sedimentation Sand Filters have been built in underground vaults in Alexandria on sheds of three-four acres of impervious cover. Precast segmented underground vaults are now available in very large configurations. Besides the modified precast box culvert technology illustrated under **MS 3.12A: D.C. Sand Filters**, precast arch technology has also been adapted to the construction of underground vaults. **Figure 3.12C-3** shows such a system. It appears that approximately five acres of impervious cover is the uper limit of the area that should be treated by a single underground vault system.

FIGURE 3.12C - 3
Underground Vault Fabricated From Precast Bridge Arch Components

(Photo Courtesy of BridgeTek Bridge Technologies, LLC., Fredericksburg, Virginia)

Development Conditions

Austin Sand Filters are generally suitable BMPs for medium to high density commercial or industrial development. Because of confined space entry restrictions when constructed in underground vaults and maintenance requirements, they are not generally suitable for residential applications except for apartment complexes or large condominiums where a dedicated maintenance force will be present.

Planning Considerations

Refer to the **Planning Considerations** for **Minimum Standard 3.12: General Intermittent Sand Filter Practices**. Of special concern are the stormwater infrastructure serving the site and the requirement to isolate the sand filter from receiving flows until the drainage shed is fully stabilized.

Potential and existing elevations of stormwater infrastructure serving the site will determine one of the most critical design parameters: the maximum depth to which runoff may be pooled over the filter and preserve a gravity flow configuration (whatever the pooling depth, there must be a minimum of five feet of clearance between the top of the filter and the top slab of the filter shell to allow filter maintenance).

*Sand filter BMPS must **never** be placed in service until all site work has been completed and stabilization measures have been installed and are functioning properly.*

Design Criteria

The purpose of this section is to provide recommendations and minimum criteria for the design of Austin Sand Filter BMPs intended to comply with the Virginia Stormwater Management program's runoff quality requirements.

Refer to the **General Design Criteria** previously discussed under **General Intermittent Sand Filter Practices, Minimum Standard 3.12**

Filter Sizing Criteria

1. *Full Sedimentation with Filtration*

In this configuration, the sedimentation basin receives the WQV and detains it for a minimum draw-down time (time required to empty the basin from a full WQV condition) of 24 hours. The effluent from the sedimentation basin is discharged into the filtration basin..

Austin conducted a literature review of sedimentation basins and slow rate filters to establish design criteria.

For filtration basins, surface area is the primary design parameter. The required surface area is a function of sand permeability, bed depth, hydraulic head and sediment loading. A filtration rate of 0.0545 gallons per minute per square foot has been selected for design criteria (10.5 feet per day or 3.4 million gallons per acre per day). This filtration rate is based on a Darcy's Law coefficient of permeability k =3.5 feet per day, an average hydraulic head (h) of three (3) feet and a sand bed depth (d_f) of 18 inches, and a filter drawdown time, t_f of 40 hours.

Substituting these values in the basic Austin Filter Formula shown in **General Intermittent Sand Filter Practices, Minimum Standard 3.12** yields:

$A_f = I_a H/18$

where "A_f" is the minimum surface area of the filtration media in acres, "I_a" is the contributing impervious runoff area in acres and "H" is the runoff depth in feet (0.5 inch = 0.0417 feet when treating the WQV).

When treating the first 1/2-inch of runoff, this formula reduces to

$A_f = 0.0023I_a = 100\ Ft^2$ of filter per impervious acre.

This formula is obviously based on a number of simplifying assumptions. Determining the actual average depth of ponding over the filter is an extremely complex proposition considering thet the runoff is being released from the sedimentation chamber to the filter at first a rising and then a falling head and then percolating through the sand filter at first a rising and then a falling head. However, this design procedure has worked well for austin for over a decade and may be therefore be considered to be vaild.

When treating a volume greater than the WQV (as when a combined quantity detention/presettling basin is utilized) use the following formula:

$A_f = 0.0023I_a \times (TV / WQV)$

Where TV = the full retention volume of the detention basin/presettling basin.

2. Partial Sedimentation with Filtration

In this configuration, the sedimentation basin or chamber holds a minimum of 20 percent of the WQV and is hydraulically connected to the filter basin with orifices or slots which allow the water level to equalize between the two chambers.

For Austin Sand Filters with partial sedimentation protection, utilize the following formula:

$$A_{fm(PS)} = \frac{545 I_a d_f}{(h + d_f)}$$

where,

I_a = impervious cover on the watershed in acres
d_f = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

Sedimentation Basin Sizing

1. *Full Sedimentation with Filtration*

The sedimentation basin must hold the entire WQV (or larger treatment volume) and release it to the filter over 24 hours. The volume of the basin is thus set by the amount of area to be treated. For sedimentation basins, the removal of discrete particles by gravity settling is primarily a function of surface loading, "Q_o/A_s ", where "Q_o " is the rate of outflow from the basin and "A_s" is the basin surface area. Basin depth is of secondary importance as settling is inhibited only when basin depths are too shallow (particle resuspension and turbulence effects). For sedimentation, surface area is the primary design parameter for a fixed minimum draw-down time, t_d, of 24 hours. Removal efficiency, E, is also a function of particle size distribution. For design purposes, the particles selected for complete removal in the sedimentation basin are those which are greater than or equal in size to silt with the following characteristics: particle diameter 0.00007 foot (20 microns) and specific gravity of 2.65. These are typical values for urban runoff .

Presettling basins are usually sized using the Camp-Hazen equation (Claytor and Schueler, 1996):

$$A_S = - (Q_O / w) \times \mathrm{Ln}\ (1 - E)$$

Where,

A_S = Surface area (ft^2) of the sedimentation basin
E = Trap efficiency, which is the target removal efficiency of suspended solids (use 90%)
w = Particle settling velocity; for silt, use 0.0004 ft/sec
Q_O = rate of outflow from the basin = WQV (or treatment volume) divided by the detention time (24 hours)

Substituting the values recommended above yields the simplified formula:

$$A_S = 0.066 \times \mathrm{WQV} \quad (ft^2)$$

For 1816 ft^3, this yields an area of 120 ft^2. However, Austin recommends that the sedimentation basin be no more that 10 feet deep, which yields a surface area approximately 115% of the basin Camp-Hazen area. The Austin formula for minimum surface area is:

$$A_S = 0.0042\ I_a$$

Where I_a is the contributing impervious runoff area in acres

2. Partial Sedimentation with Filtration

The minimum area of the sediment chamber may be computed by the formula:

$$A_S = \mathrm{WQV} / 2h$$

Where 2h = the maximum depth of ponding over the filter and the sediment chamber.

Additional Full Sedimentation Basin Considerations

1. *Inlet Structure*

The inlet structure design must be adequate for isolating the water quality volume from the design storm and to convey the peak flow for the design storm past the basin. The water quality volume should be discharged uniformly and at low velocity into the sedimentation basin in order to maintain near quiescent conditions which are necessary for effective treatment. It is desirable for the heavier suspended material to drop out near the front of the basin; thus a drop inIet structure is recommended in order to facilitate sediment removal and maintenance. Energy dissipation devices may be necessary in order to reduce inlet velocities which exceed three (3) feet per second.

2. *Outlet Structure*

The outlet structure conveys the water quality volume from the sedimentation basin to the filtration basin. The outlet structure shall be designed to provide for a minimum draw-down time of 24 hours. A perforated pipe or equivalent is the recommended outlet structure. The 24 hour draw-down time should be achieved by installing a throttle plate or other flow control device at the end of the riser pipe (the discharges through the perforations should not be used for draw-down time design purposes)

3. *Basin Geometry*

The shape of the sedimentation basin and the flow regime within this basin will influence how effectively the basin volume is utilized in the sedimentation process. The length to width ratio of the basin should be 2:1 or greater. Inlet and outlet structures should be located at extreme ends of the basin in order to maximize particle settling opportunities.

Short-circuiting (i.e., flow reaching the outlet structure before it passes through the sedimentation basin volume) flow should be avoided. Dead storage areas (areas within the basin which are by-passed by the flow regime and are, therefore, ineffective in the settling process) should be minimized. Baffles may be used to mitigate short circuiting and/or dead storage problems. The sedimentation illustrated in **Figure 3.12C-1** (photo in **Figure 3.12-4**) illustrates the use of baffles to improve sedimentation basin performance.

4. *Sediment Trap (Optional)*

A sediment trap is a storage area which captures sediment and removes it from the basin flow regime. In so doing the sediment trap inhibits resuspension of solids during subsequent runoff events, improving long-term removal efficiency. The trap also maintains adequate volume to hold the water quality volume which would otherwise be partially lost due to sediment storage. Sediment traps may reduce maintenance requirements by reducing the frequency of sediment removal. It is recommended that the sediment trap volume be equal to ten (10) percent of the sedimentation basin volume. Water collected in the sediment trap shall be conveyed to the filtration basin in order to prevent standing water conditions from occurring. All water collected in the sediment trap shall drain out within 60 hours. The invert of the drain pipe should be above the surface of the sand bed filtration basin. The minimum grading of the piping to the filtration basin should be 1/4 inch per foot (two (2) percent slope). Access for cleaning the sediment trap drain system is necessary.

Design Storm

The inlet design or integral large storm bypass must be adequate for isolating the WQV from the design storm for the receiving storm sewer system (usually the 10 year storm) and for conveying the peak flow of that storm past the filter system. Since D.C. Sand Filters will be used only as off-line facilities in Virginia, the interior hydraulics of the filter are not as critical as when used as an on-line facility. The system should draw down in approximately 40 hours.

Infrastructure Elevations

For cost considerations, it is preferable thatAustin Sand Filters work by gravity flow. This requires sufficient vertical clearance between the invert of the prospective inflow storm piping and the invert of the storm sewer which will receive the outflow. In cases where gravity flow is not possible, a clearwell sump and pump are required to discharge the effluent into storm sewer. Such an application would be appropriate in commercial or industrial situations where a dedicated maintenance force will be available (shopping malls, apartment houses, factories of other industrial complexes, etc.).

Special Considerations for Underground Filter Systems

When Austin Sand Filters are placed underground, a number of special considerations pertain. The restrictive orifice or gate valve for controlling the release of water from a separate sedimentation vault should be placed in a manhole located between the sedimentation vault and the filter vault. The sedimentation vault should contain a sediment sump into which accumulated sediments may be flushed with a high pressure hose for removal by vacuum trucks. Water should enter the filter vault in a separate headbox with a permanent pool for energy absorbtion and a hydrocarbon trap like that of a D.C. Sand Filter. The filter vault should also contain a separate clearwell.

Structural Requirements

The load-carrying capacity of the filter structure must be considered when it is located under parking lots, driveways, roadways, and, certain sidewalks (such as those adjacent to State highways). Traffic intensity may also be a factor. The structure must be designed by a licensed structural engineer and the structural plans require approval by the plan approving jurisdiction.

Accessibility and Headroom for Maintenance

Both the sedimentation basin and the filter must be accessible to appropriate equipment and vacuum trucks for removing accumulated sediments and trash. The sedimentation basin must be cleaned approximately once per year, and the filter will likely need raking on that frequency to remove trash and restore permeability. When filters are placed in underground vaults, all chambers must have personnel access manholes and built-in access ladders. **A minimum headspace of 60 inches above the filter is required to allow such maintenance and repair.** A 38-inch diameter maintenance manhole with eccentric nested covers (a 22-inch personnel access lid inside the 38-inch diameter lid) or a rectangular load bearing access door (minimum 4 ft. x 4 ft.) should be positioned directly over the center of the filter. A 30-inch manhole should also be placed directly over the sediment sump in an underground sedimentation vault. Similar manholes must be positioned to provide access for a high-pressure hose to reach all points in the sediment vault.

Construction Specifications

Sedimentation Basin Liners

Impermeable liners may be either clay, concrete or geomembrane. If geomembrane is used, suitable geotextile fabric shall be placed below and on the top of the membrane for puncture protection. Clay liners shall meet the specifications in **Table 3.12C-2**:

The clay liner shall have a minimum thickness of 12 inches.

If a geomembrane liner is used it shall have a minimum thickness of 30 mils and be ultraviolet resistant.

The geotextile fabric (for protection of geomembrane) shall meet the specifications in **Table 3.12C-3**.

TABLE 3.12C - 2
Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	Cm/Sec	1 x 10^{-6}
Plasticity Index of Clay	ASTM D-423 & D-424	%	Not less than 15
Liquid Limits of Clay	ASTM D-2216	%	Not less than 30
Clay Compaction	ASTM-2216	%	95% of Standard Proctor Density
Clay Particles Passing	ASTM D-422	%	Not less than 30

Source: City of Austin

TABLE 3.12C - 3
Geotextile Specification for Basin Liner "Sandwich"

Property	Test Method	Unit	Specification
Unit Weight		Oz./Sq.Yd.	8 (minimum)
Filtration Rate		In./Sec.	0.08 (minimum)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (minimum)
Mullen Burst Strength	ASTM D-751	Psi.	400 (minimum)
Tensile Strength	ASTM D-1682	Lb.	300
Equiv. Opening Size	U.S. Standard Sieve	No.	80 (minimum)

Source: City of Austin

Equivalent methods for protection of the geomembrane liner will be considered on a case by case basis. Equivalency will be judged on the basis of ability to protect the geomembrane from puncture, tearing and abrasion.

Portland Cement Concrete

Concrete liners may be used for sedimentation chambers and for sedimentation and filtration basins. Concrete shall be at least five (5) inch thick Class A3 defined in the Virginia Department of Transportation *Road and Bridge Specifications.*

Outlet Structure for Full Sedimentation Basin

A perforated pipe or equivalent is the recommended outlet structure. The 24-hour draw-down should be achieved by installing a throttle plate or other control device at the end of the riser pipe (the discharges through the perforations should not be used for draw-down time design purposes). The perforated riser pipe should be selected from **Table 3.12-4.**

TABLE 3.12C - 4
Perforated Riser Pipes

Riser Pipe Nominal Diameter (inches)	Vertical Spacing Between Rows (Center to Center in Inches)	Number of Perforations Per Row	Diameter of Perforations (inches)
6	2.5	9	1
8	2.5	12	1
10	2.5	16	1

Source: City of Austin

A trash rack shall be provided for the outlet. Openings in the rack should not exceed 1/3 the diameter of the vertical riser pipe. The rack should be made of durable material, resistant to rust and ultraviolet rays. The bottom rows of perforations of the riser pipe should be protected from clogging. To prevent clogging of the bottom perforations it is recommended that geotextile fabric be wrapped over the pipe's bottom rows and that a cone of one (1) to three (3) inch diameter gravel be placed around the pipe. If a geotextile fabric wrap is not used then the gravel cone must not include any gravel small enough to enter the riser pipe perforations. **Figure 3.12C-4** illustrates these considerations.

Outlet Structure for Partial Sedimentation Basin

The outlet structure should be a berm or wall with multiple outlet ports or a gabion so as to discharge the flow evenly to the filtration basin. Rock gabions should be constructed using 6-8 inch diameter rocks. The berm/wall/gabion height should not exceed six (6) feet and high flows should be allowed to overtop the structure (weir flow). Outlet ports should not be located along the vertical center axis of the berm/wall so as to induce flow-spreading. The outflow side should incorporate features to prevent gouging of the sand media (e.g., concrete splash pad or riprap)

Sand Filter Layer

For applications in Virginia, use **ASTM C33 Concrete Sand** or sand meeting the Grade A fine aggregate gradation standards of Section 202 of the VDOT ***Road and Bridge Specifications.*** The top of the sand filter must be completely level.

Geotextile Fabrics

The filter cloth layer beneath the sand shall conform to the specifications shown in **Table 3.12C-5**: The fabric rolls must be cut with sufficient dimensions to cover the entire wetted perimeter of the filtering area and lap up the filter walls at least six-inches.

FIGURE 3.12C - 4
Riser Pipe Detail for Full Sedimentation Basin

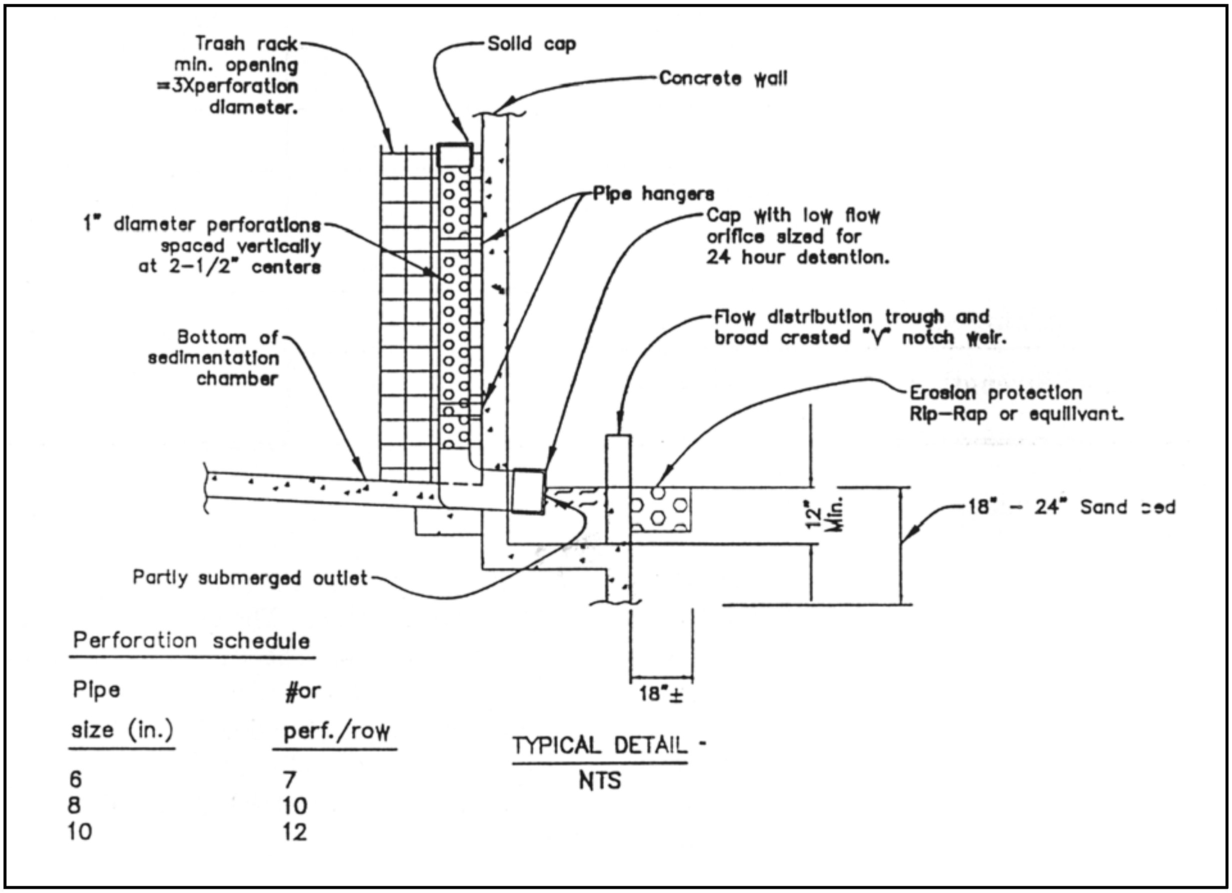


Table 3.12C - 5
Specifications for Nonwoven Geotextile Fabric Beneath Sand in Austin Sand Filter

Property	Test Method	Unit	Specification
Unit Weight	--	Oz./sq.yd.	8.0 (min.)
Filtration Rate	--	In/sec	0.08 (min.)
Puncture Strength	ASTM D-751 (Modified)	Lb.	125 (min.)
Mullen Burst Strength	ASTM D-751	Psi	400 (min.)
Equiv. Opening Size	U.S. Standard Sieve	No.	80 (min.)
Tensile Strength	ASTM D-1682	Lb.	300 (min.)

Gravel Bed Around Collector Pipes

The gravel layer surrounding the collector pipes shall be ½ to two (2) inch diameter gravel and provide at least two (2) inches of cover over the tops of the drainage pipes. The gravel and the sand layer are usually separated by a layer of geotextile fabric meeting the specification listedabove. However, on small underground vault partial sedimentation systems, some jurisdictions allow the substitution for an additional six-inch layer of 1/4-inch washed pea gravel in lieu of the filter fabric. In such cases, hydraulic compaction and refilling of the filter is especially important. **FIGURE 3.12C-5** shows a cross-section of a filter with the usual configuration. **FIGURE 3.12C-6** shows an underground vault filter with a six-inch pea gravel layer.

Underdrain Piping

The underdrain piping consists of 4-inch or 6-inch schedule 40 or better polyvinyl perforated pipes reinforced to withstand the weight of the overburden. Perforations should be 3/8 inch, and each row of perforations shall contain at least four holes for four-inch pipe and six holes for six-inch pipe. Maximum spacing between rows of perforations shall be six (6) inches. Maximum spacing between pipes shall be 10 feet.

The minimum grade of piping shall be 1/8 inch per foot (one [1] percent slope). Access for cleaning all underdrain piping is needed. Clean-outs for each pipe shall extend at least six (6) inches above the top of the upper filter surface, e.g. the top layer of gravel.

Each pipe shall be thoroughly wrapped with 8 oz./sq.yd. geotextile fabric meeting the specification in **Table 3.12C-1** above.

FIGURE 3.12C - 5
Austin Sand Filter Cross-Section With Filter Fabric Layer

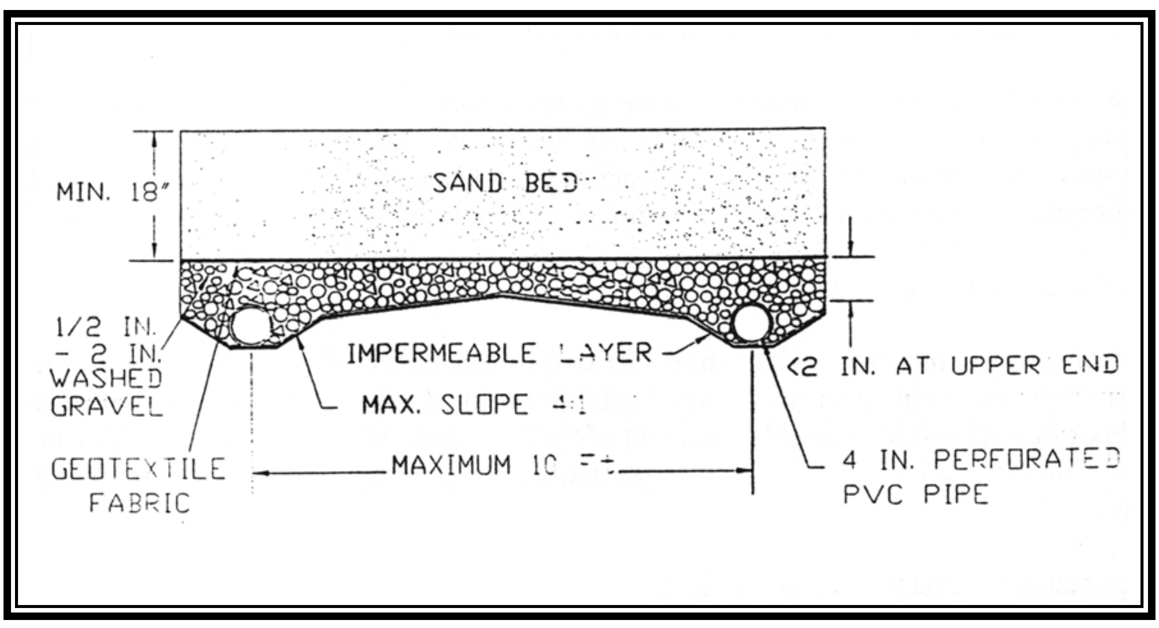
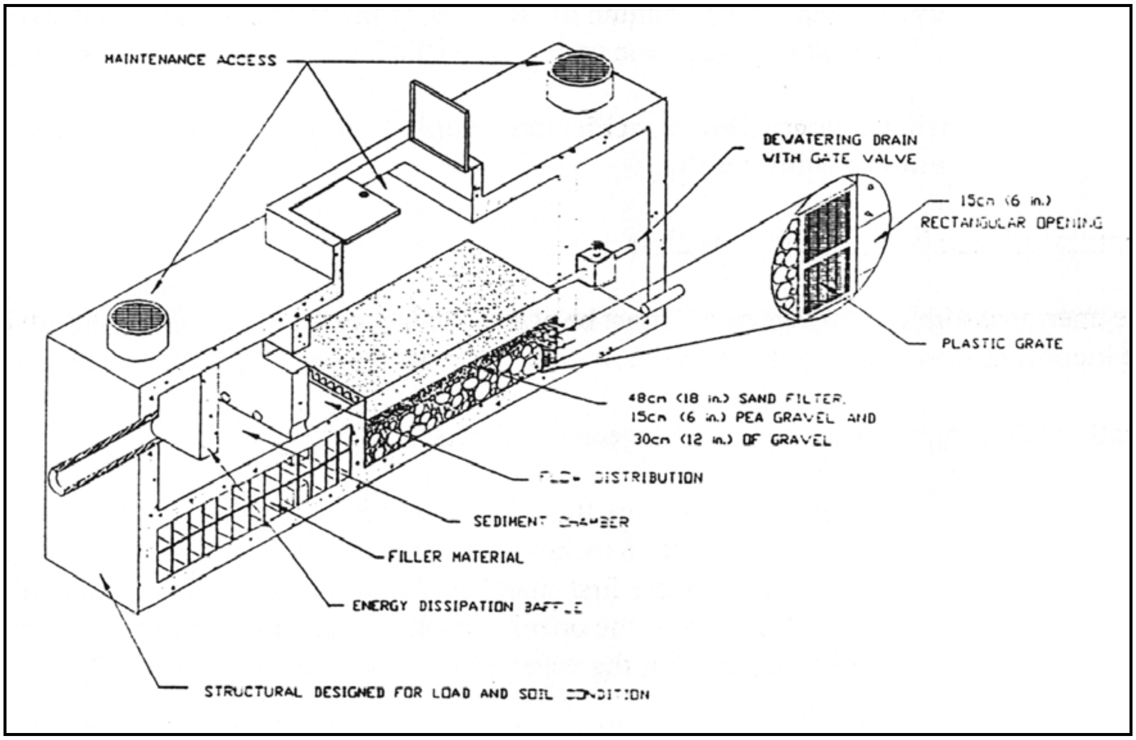


FIGURE 3.12C - 6
Partial Sedimentation Vault Filter With Pea Gravel Layer



Protection from Construction Sediments

The site erosion and sediment control plan must be configured to permit construction of the filter system while maintaining erosion and sediment control.

No runoff is to enter the sand filtration system prior to completion of all construction and site revegitation. Construction runoff shall be treated in separate sedimentation basins and routed to by-pass the filter system. Should construction runoff enter the filter system prior to site revegitation, all contaminated materials must be removed and replaced with new clean materials.

Watertight Integrity Test

After completion of the filter shell but before placement of the filter layers, entrances to the structure shall be plugged and the shell completely filled with water to demonstrate water tightness. Maximum allowable leakage is 5 percent of the filter shell volume in 24 hours. Should the structure fail this test, it shall be made watertight and successfully retested prior to placement of the filter layers.

Hydraulic Compaction of Filter Components

After placement of the collector pipes, gravel, and lower geotextile layer, fill the shell with filter sand to the level of the top of the sediment pool weir. Direct clean water into the sediment chamber until both the sediment chamber and filter chamber are completely full. Allow the water to draw down until flow from the collector pipes ceases, hydraulically compacting the filter sand. After allowing the sand to dry out for a minimum of 48 hours, refill the shell with sand to a level one inch beneath the top of the weir and place the upper geotextile layer and gravel ballast.

Note: The following Construction Specifications apply to Austin Sand Filters which are to be constructed in underground vaults.

Depth of Plunge Pool in Filter Headbox

The energy absorbing "plunge pool" must be at least 36 inches deep to properly absorb energy from the incoming flow and trap any hydrocarbons which pass through the sedimentation vault.

Depth of the Underwater Opening Between Chambers

To preserve an effective hydrocarbon trap, the top of the underwater opening between the headbox and the filter chamber must be at least 18 inches below the depth of the weir which divides the filter from the pool. To retain sediment in the first chamber, the bottom of the opening should be at least six inches above the floor. The area of the opening should be at least 1.5 times the cross-sectional area of the inflow pipe(s) to assure that the water level remains equal between the first and second chambers.

Total Depth of Filter Cross-Section

The total depth of the filter cross-section must match the height of the weir dividing the sedimentation pool from the filter. Otherwise, a "waterfall" effect will develop which will gouge out the front of the filter media. If a sand filter less than 24 inches is used, the gravel layer must be increased accordingly to preserve the overall filter depth.

Dewatering Drain

When the filter is placed in an underground vault, A 6-inch dewatering drain controlled by a gate valve shall be installed between the filter chamber and the clearwell chamber with its invert at the elevation of the top of the filter. The dewatering drain penetration in the chamber dividing wall shall be sealed with a flexible strip joint sealant which swells in contact with water to form a tight pressure seal.

Access Manholes

When the filter is installed in an underground vault, access to the headbox (sediment chamber) and the clearwell shall be provided through at least 22-inch manholes. Access to the filter chamber shall be provided by a rectangular door (minimum size: 4 feet by four feet) of sufficient strength to carry prospective imposed loads or by a manhole of at least 3- inch diameter with an offset concentric 22-inch lid (Neenah R-1741-D or equivalent).

Restrictive Orifice Manhole Between Vaults

The restrictive orifice or gate valve on the outlet pipe from the sedimentation vault should be placed in a manhole between the sedimentation and filter vaults with ready personnel access. **Figure 3.12C-7** illustrates this principle.

Maintenance/Inspection Guidelines

The following maintenance and inspection guidelines are not intended to be all inclusive. Specific facilities may require other measures not discussed here.

Major Maintenance Requirements for Sedimentation Basins

1. Removal of silt when accumulation exceeds six (6) inches in sediment basins without sediment traps. In basins with sediment traps, removal of silt shall occur when the accumulation exceeds four (4) inches in the basins, and sediment traps shall be cleaned when full.

2. Removal of accumulated paper, trash and debris every six (6) months or as necessary.

3. Vegetation growing within the basin is not allowed to exceed 18 inches in height at any time.

4. Corrective maintenance is required any time a sedimentation basin does not drain the equivalent of the Water Quality Volume within 40 hours (i.e., no standing water is allowed).

5. Corrective maintenance is required any time the sediment trap (optional) does not drain down completely within 96 hours (i.e., no standing water allowed).

Major Maintenance Requirements for Filtration Components

1. Removal of silt when accumulation exceeds 1/2 inch. - Removal of accumulated paper, trash and debris every six (6) months or as necessary.

2. Vegetation growing within the basin is not allowed to exceed 18 inches in height.

3. Corrective maintenance is required any time draw-down does not occur within 36 hours after the sedimentation basin has emptied.

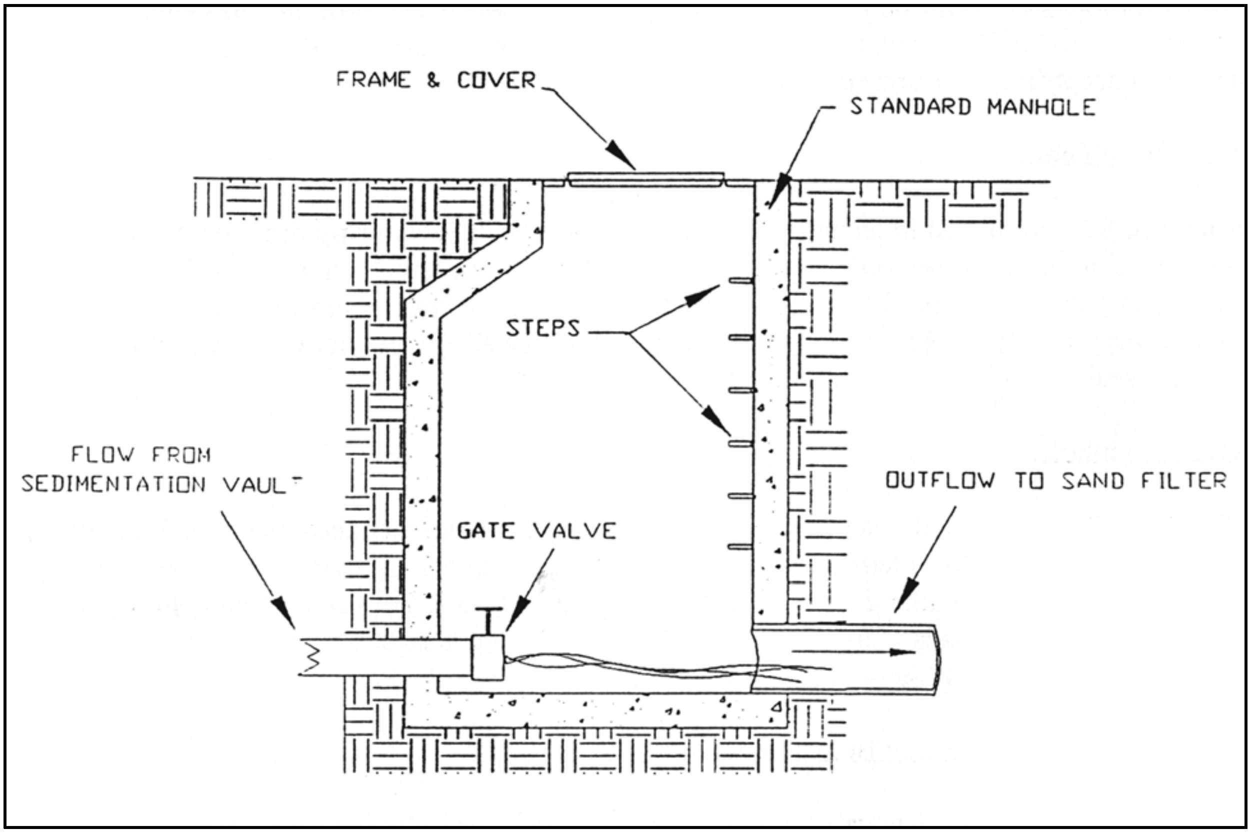
4. When an underground vault filter will no longer draw down within the required 36-hour period because of clogging with silt (approximately every 3-5 years), the upper layer of gravel and

geotechnical cloth must be replaced with new clean materials meeting the original specifications.

5. Monitoring manholes, flumes, and other facilities shall be kept clean and ready for use.

The BMP shall be inspected annually by representatives of the owner and the governing jurisdiction staff to assure continued proper functioning.

FIGURE 3.12C - 7
Restrictive Orifice Access Manhole



Sediment Chamber Pumpout

Full sedimentation chambers or basins require flushing and pumpout with a vacuum truck approximately once per year.

Concrete Shell Inspection

Concrete will deteriorate over time, especially if subjected to live loads. The concrete shell, risers, etc., must be examined during each annual inspection to identify areas that are in need of repair, and such repairs must be promptly effected.

Design Procedures

The following design procedure is structured to assure that the desired water quality volume is captured and treated by theAustin Filter. The procedure assumes that a filter shell with a rectangular cross-section is to be used.

Standard Design Logic

Employ the following design logic to design Austin Sand Filters for use in Virginia:

1. Determine Governing Site Parameters

Determine the Impervious area on the site (I_a in acres), the water quality volume to be treated (WQV in $ft.^3 = 1816\ I_a$), and the site parameters necessary to establish 2h, the maximum ponding depth over the filter (storm sewer invert at proposed connection point, elevation to inflow invert to BMP, etc).

2. Select Filter Depth and Determine Maximum Ponding Depth

Considering the data from Step 1) above, select the Filter Depth ((d_f) and determine the maximum achievable ponding depth over the filter (2h).

3. For Full Sedimantation Systems, size the sedimentation basin (vault) to hold the WQV with a minimum depth of 10 feet.

4. Compute the Minimum Area of the Sand Filter (A_{fm})

For systems with full sediment protection, provide a dediment chamber of sufficient volume to hold the WQV. Make the depth ≤ ten feet. To compute the area of the filter, use the formula:

$$A_f = 100I_a$$

Where I_a = the impervious acreage on the drainage shed.

For systems with only partial sediment protection, utilize the formula:

$$A_{fm(PS)} = \frac{545I_a d_f}{(h + d_f)}$$

A_{fm} = minimum surface area of sand bed (square feet)
I_a = impervious cover on the watershed in acres
d_f = sand bed depth (normally 1.5 to 2ft)
h = average depth of water above surface of sand media between full and empty basin conditions (ft.)

5. Select Filter Width and Compute Filter Length and Adjusted Filter Area

Considering site constraints, select the Filter Width (W_f). Then compute the Filter Length (L_f) and the Adjusted Filter Area (A_f)

$$L_f = A_{fm}/W_f$$

$$A_f = W_f \text{ x } L_f$$

Sizing computations are completed at this point for the full sediment protection system. The only remaining task is to assure that the filter chamber is sized to contain a minimum of 20 % of the WQV. The logic continues for the partial sedimentation system.

6. Compute the Storage Volume on Top of the Filter (V_{Tf})

$$V_{Tf} = A_f \text{ x } 2h$$

7. Compute the Storage in the Filter Voids (V_v)
(Assume 40% voids in filter media)

$$V_v = 0.4 \text{ x } A_f \text{ x } (d_f + d_g)$$

8. Compute Flow Through Filter During Filling (V_Q)
(Assume 1-hour to fill per D.C. practice)

$$V_Q = \frac{kA_f(d_f + h)}{d_f} \text{ ; use } k = 2 \text{ ft./day} = 0.0833\text{/hr.}$$

9. Compute Net Volume to be Stored Awaiting Filtration (V_{st})

$$V_{st} = WQV - V_{Tf} - V_v - V_Q$$

10. Compute Length of Sediment chamber (L_{SC})

$$L_{SC} = \frac{V_{st}}{(2h \text{ x } W_f)}$$

11. Compute Minimum Length of Sediment Chamber (L_s)
(to contain 20% of WQV per Austin practice)

$$L_{sm} = \frac{0.2WQV}{(2h \text{ x } W_f)}$$

12. Set Final Length of the Sediment Chamber (L_{SCF})

If $L_{SC} \geq L_s$, make $L_{SCF} = L_{SC}$

If $L_{SC} < L_{sm}$, make $L_{SCF} = L_{sm}$

It may be economical to adjust final dimensions to correspond with standard precast structures or to round off to simplify measurements during construction.

Checklists

The **Construction Inspection and As-Built Survey Checklist** found in **Appendix 3D** is for use in inspecting intermittent sand filter facilities during construction and, where required by the local jurisdiction, engineering certification of the filter construction. The **Operation and Maintenance Checklist**, also found in **Appendix 3D**, is for use in conducting maintenance inspections of intermittent sand filter facilities.

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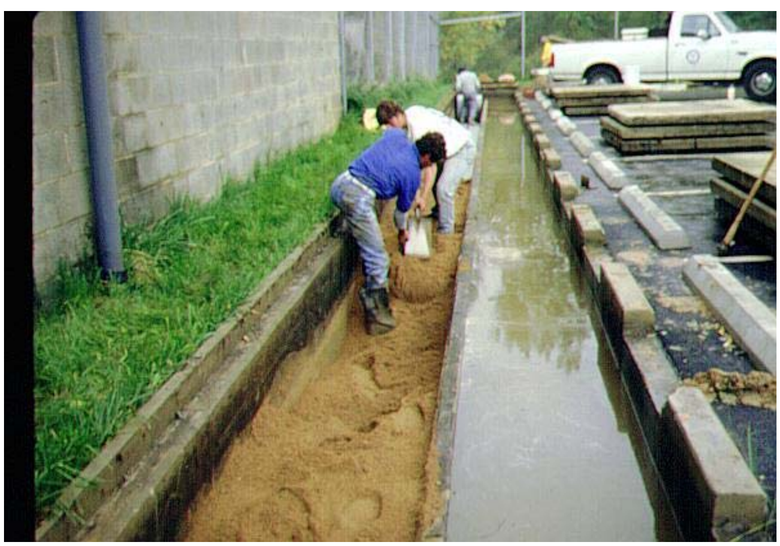
Chapter 3.12

Sand Filter at entrance to service station.



Sand Filter under construction. Note curb cuts for inflow to wet chamber with weir overflow into sand chamber.

General Intermittent Sand Filters